Fig.1

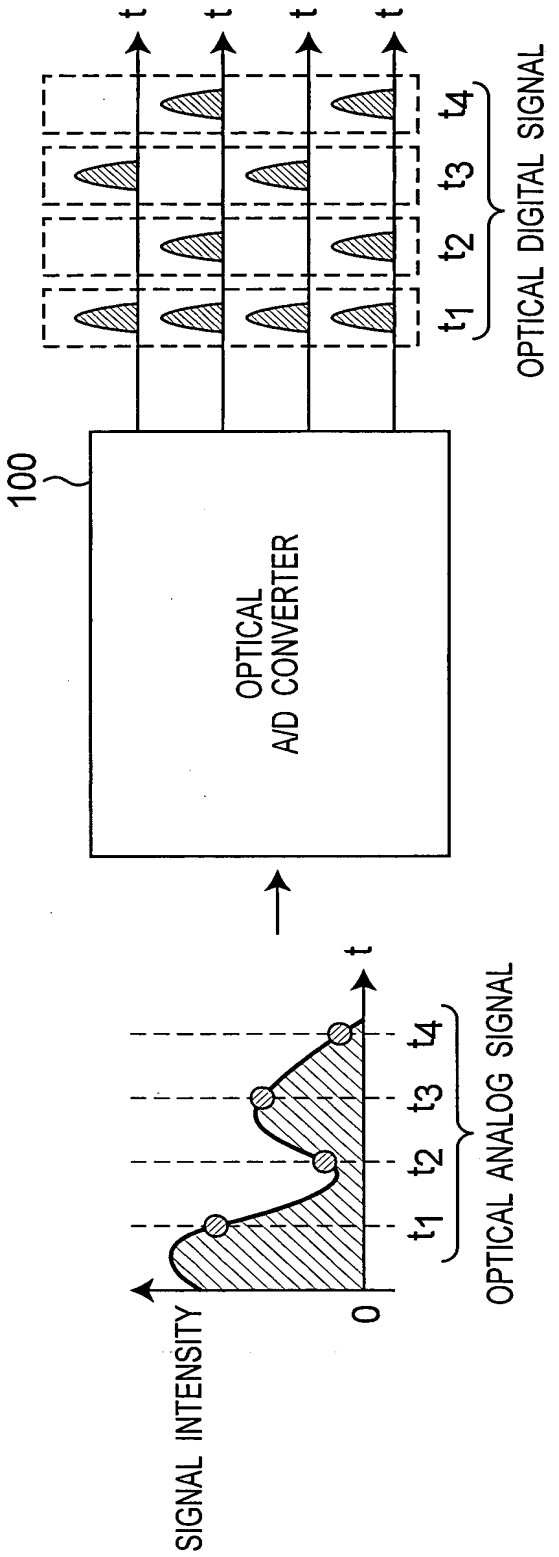

SIGNAL INTENSITY
0
t
t1 t2 t3 t4
OPTICAL ANALOG SIGNAL
100
OPTICAL
A/D CONVERTER
t
t
t
t
t1 t2 t3 t4
OPTICAL DIGITAL SIGNAL

Fig.2

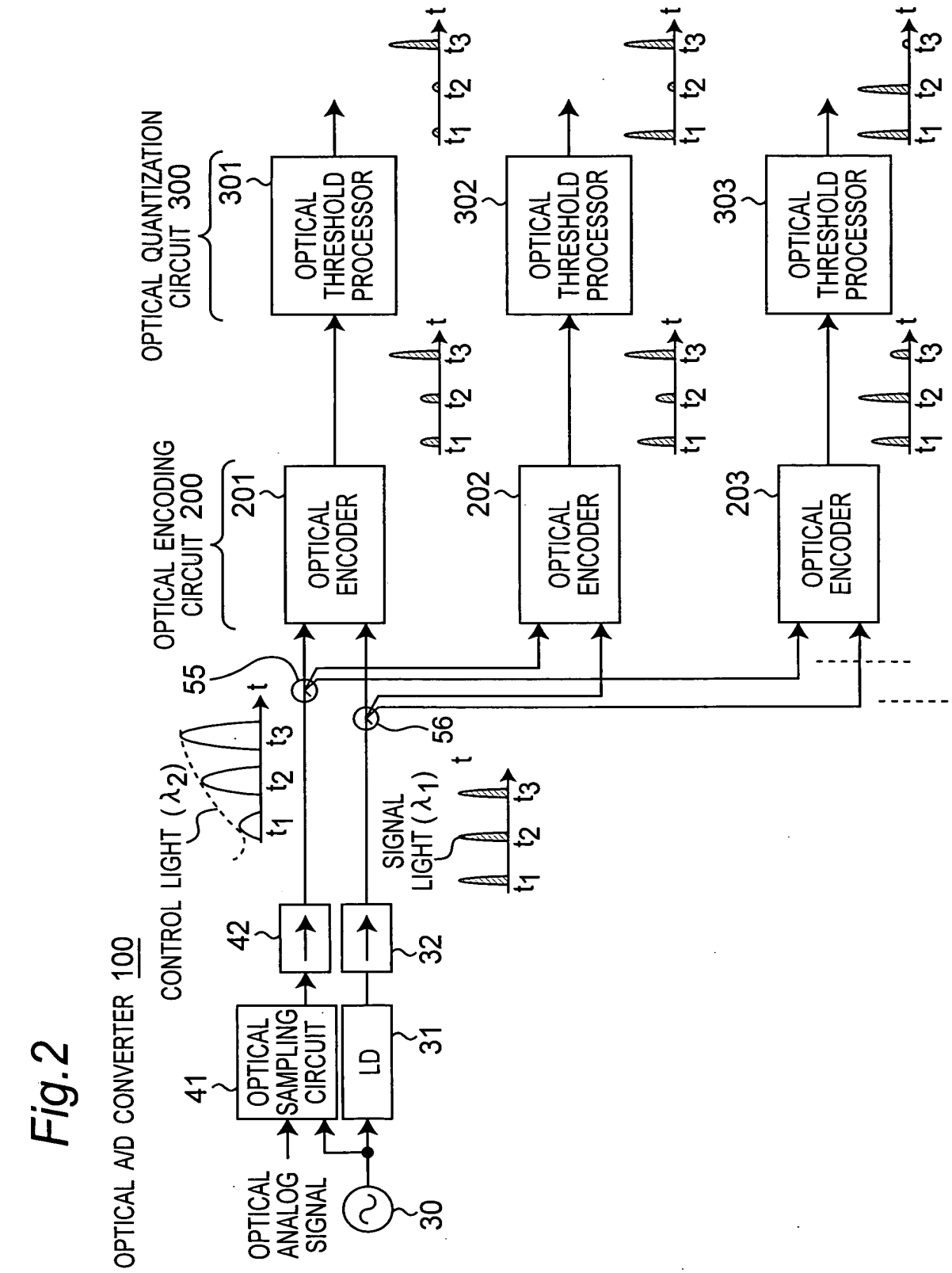

OPTICAL A/D CONVERTER 100
OPTICAL ANALOG SIGNAL
30
LD
31
OPTICAL SAMPLING CIRCUIT
41
42
32
CONTROL LIGHT (λ2)
SIGNAL LIGHT (λ1)
t1 t2 t3
t
55
56
OPTICAL ENCODING CIRCUIT 200
OPTICAL QUANTIZATION CIRCUIT 300
201
202
203
301
302
303
OPTICAL ENCODER
OPTICAL THRESHOLD PROCESSOR

Fig.3

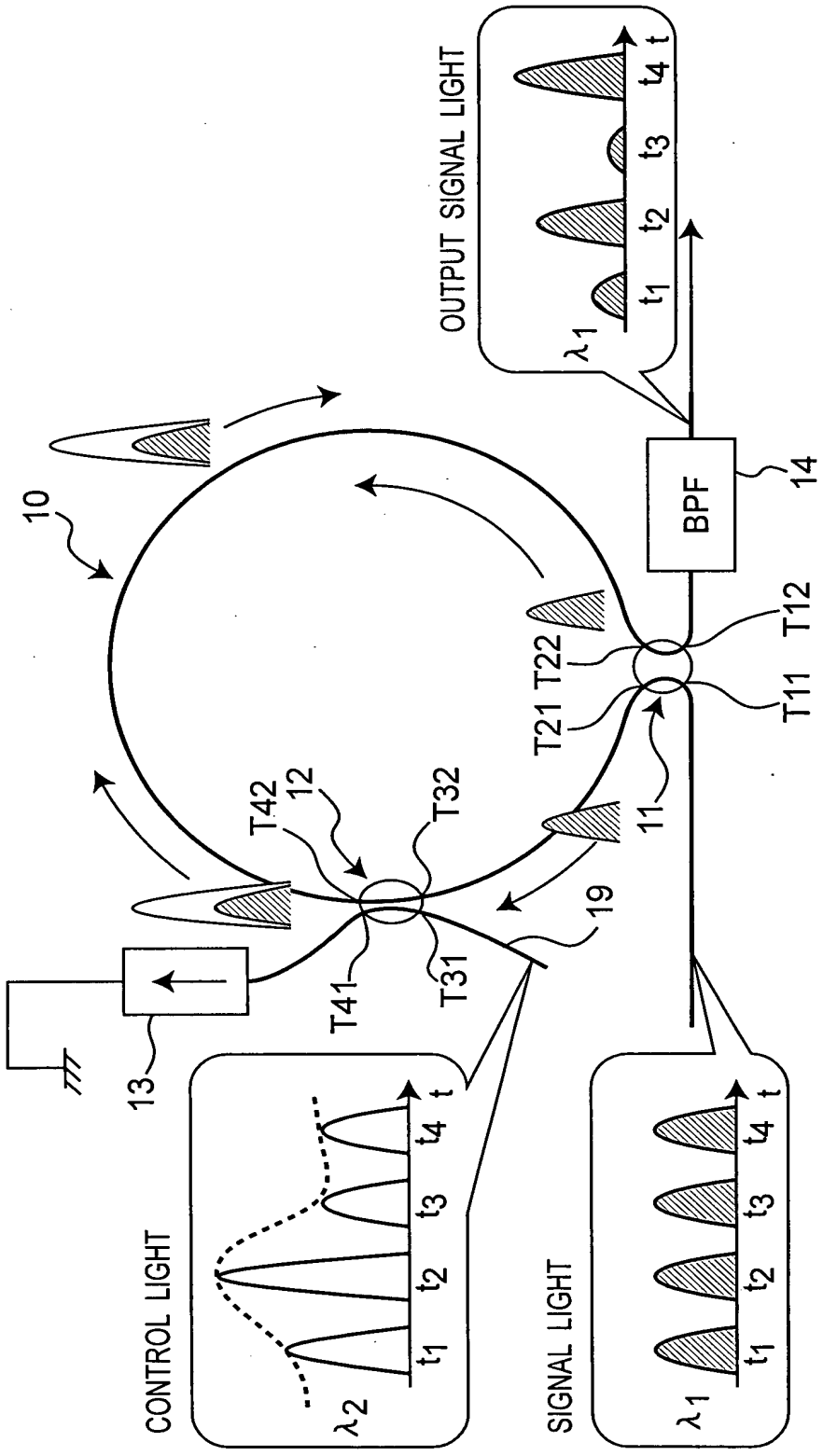

OPTICAL ENCODER 201
10
11
12
13
14
19
BPF
T11
T12
T21
T22
T31
T32
T41
T42
OUTPUT SIGNAL LIGHT
CONTROL LIGHT
SIGNAL LIGHT
λ1
λ2
t1
t2
t3
t4
t

Fig.4

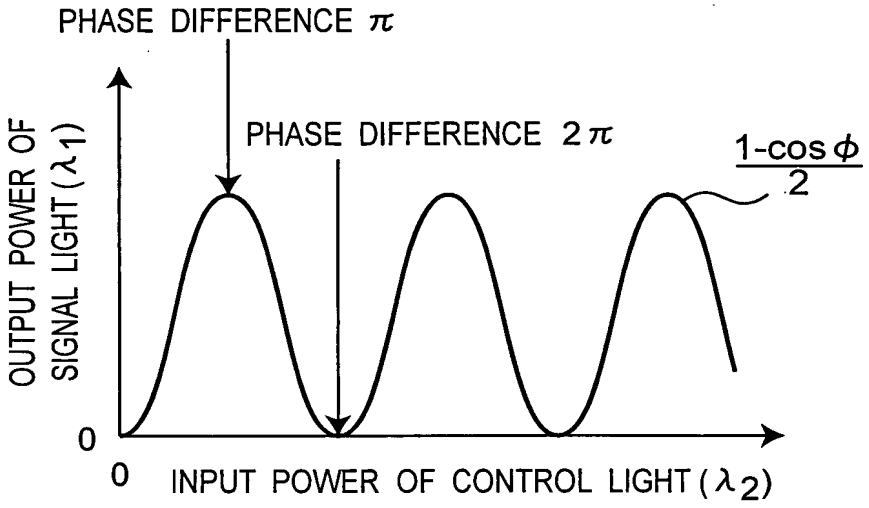

PHASE DIFFERENCE π
PHASE DIFFERENCE 2π
1-cos φ / 2
OUTPUT POWER OF SIGNAL LIGHT (λ1)
0
0
INPUT POWER OF CONTROL LIGHT (λ2)

Fig.5

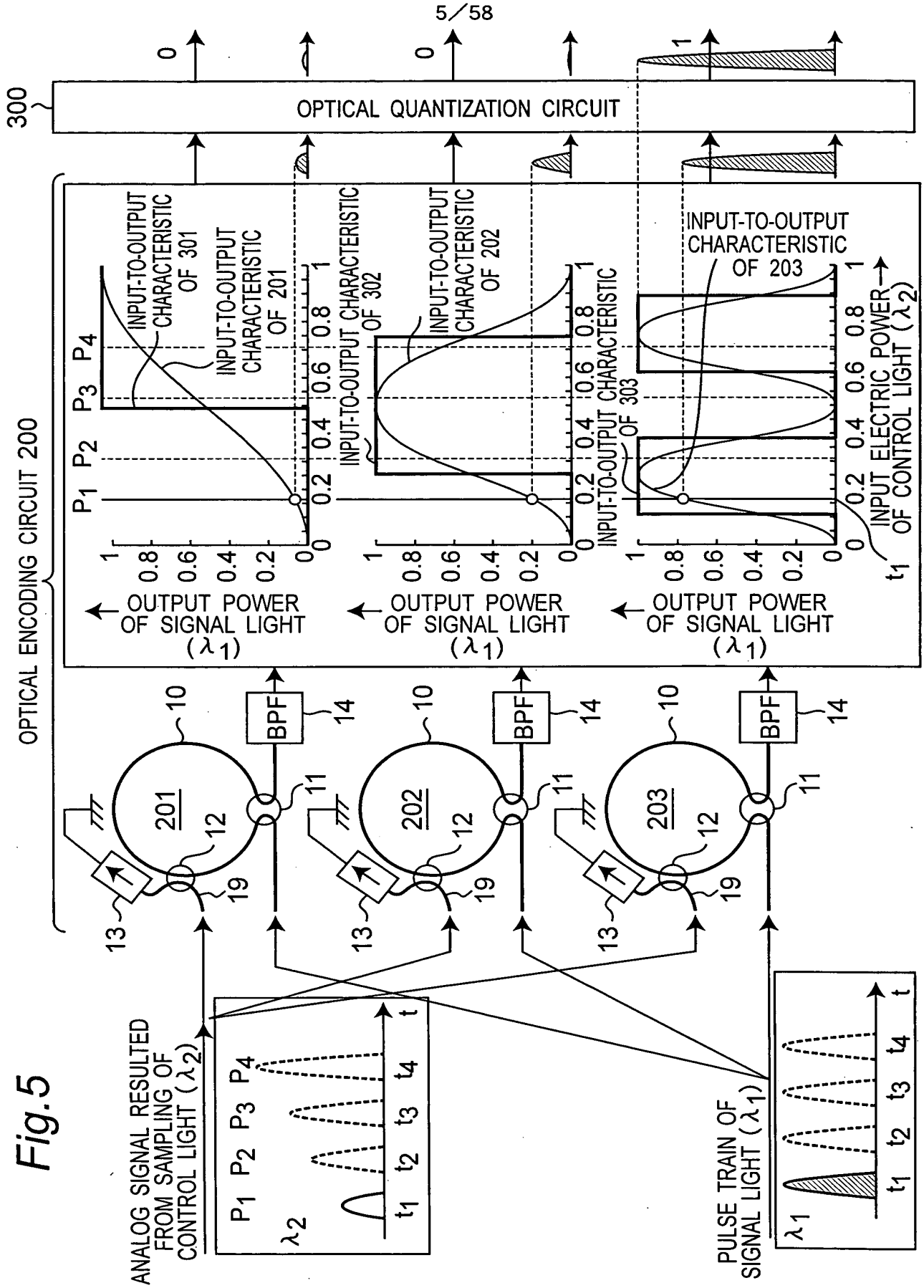
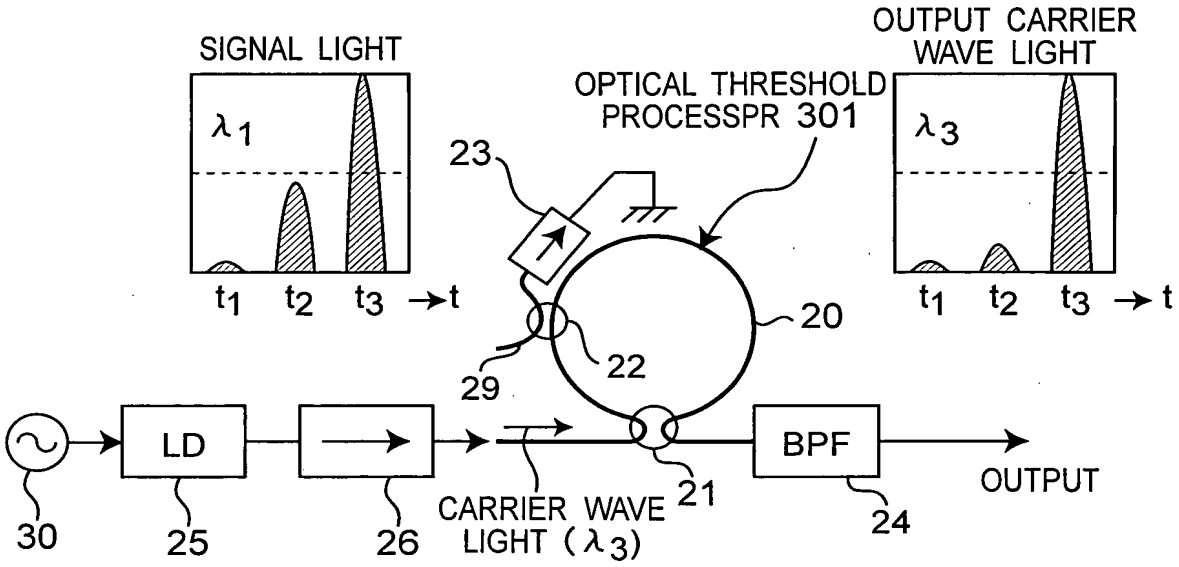

300
OPTICAL QUANTIZATION CIRCUIT
OPTICAL ENCODING CIRCUIT 200
INPUT-TO-OUTPUT CHARACTERISTIC OF 301
INPUT-TO-OUTPUT CHARACTERISTIC OF 201
INPUT-TO-OUTPUT CHARACTERISTIC OF 302
INPUT-TO-OUTPUT CHARACTERISTIC OF 202
INPUT-TO-OUTPUT CHARACTERISTIC OF 303
INPUT-TO-OUTPUT CHARACTERISTIC OF 203
P1 P2 P3 P4
OUTPUT POWER OF SIGNAL LIGHT (λ1)
INPUT ELECTRIC POWER OF CONTROL LIGHT (λ2)
t1
201
202
203
10
11
12
13
14
19
BPF
ANALOG SIGNAL RESULTED FROM SAMPLING OF CONTROL LIGHT (λ2)
PULSE TRAIN OF SIGNAL LIGHT (λ1)
λ1
λ2
t1 t2 t3 t4 t

Fig.6


SIGNAL LIGHT
λ1
t1 t2 t3 →t
OPTICAL THRESHOLD PROCESSPR 301
23
20
22
29
OUTPUT CARRIER WAVE LIGHT
λ3
t1 t2 t3 →t
LD
BPF
OUTPUT
30
25
26
CARRIER WAVE LIGHT (λ3)
21
24

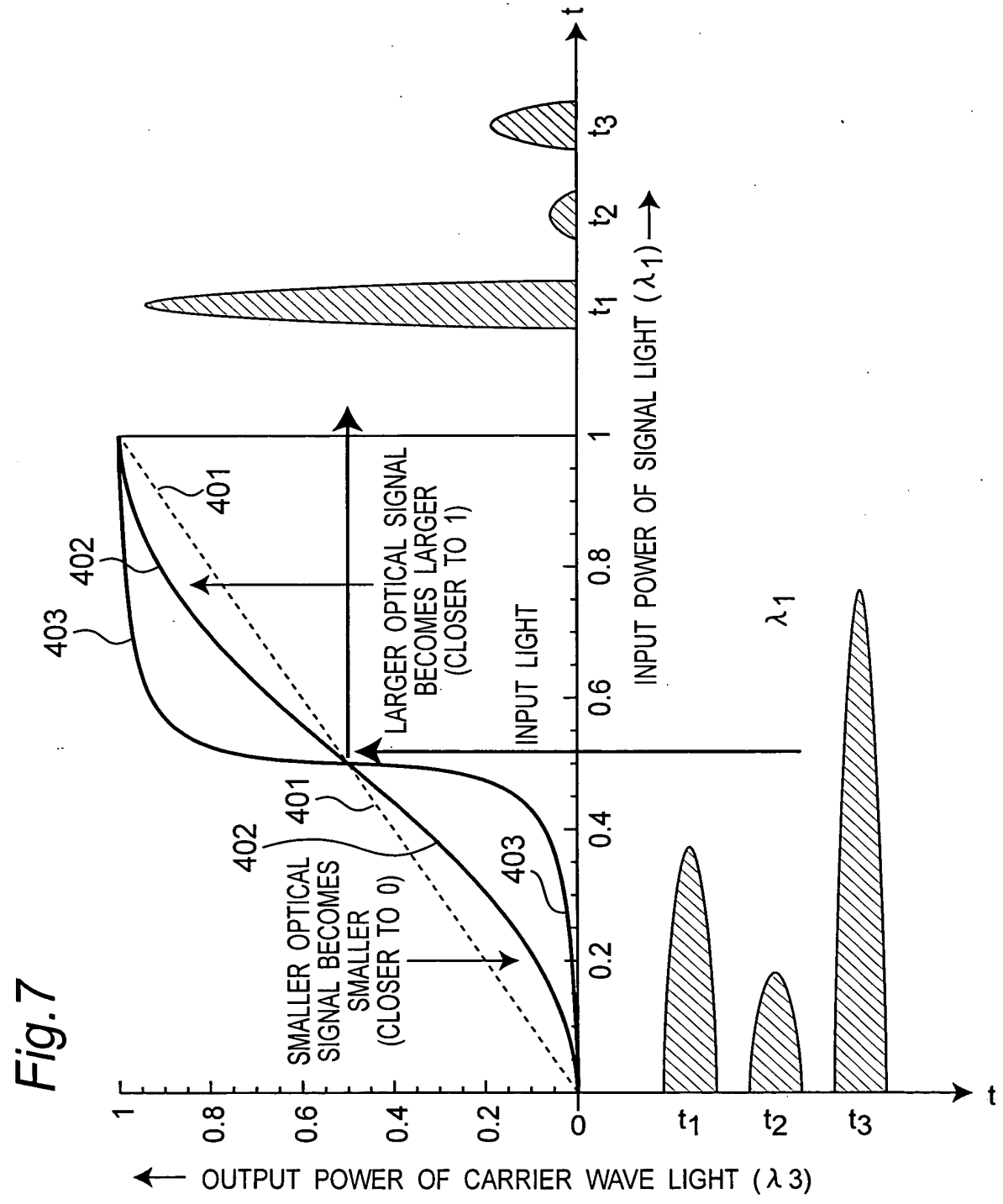

t
t3
t2
t1
INPUT POWER OF SIGNAL LIGHT (λ1)
1
0.8
0.6
0.4
0.2
0
401
402
403
LARGER OPTICAL SIGNAL BECOMES LARGER (CLOSER TO 1)
INPUT LIGHT
λ1
SMALLER OPTICAL SIGNAL BECOMES SMALLER (CLOSER TO 0)
OUTPUT POWER OF CARRIER WAVE LIGHT (λ3)

Fig.7

Fig.8

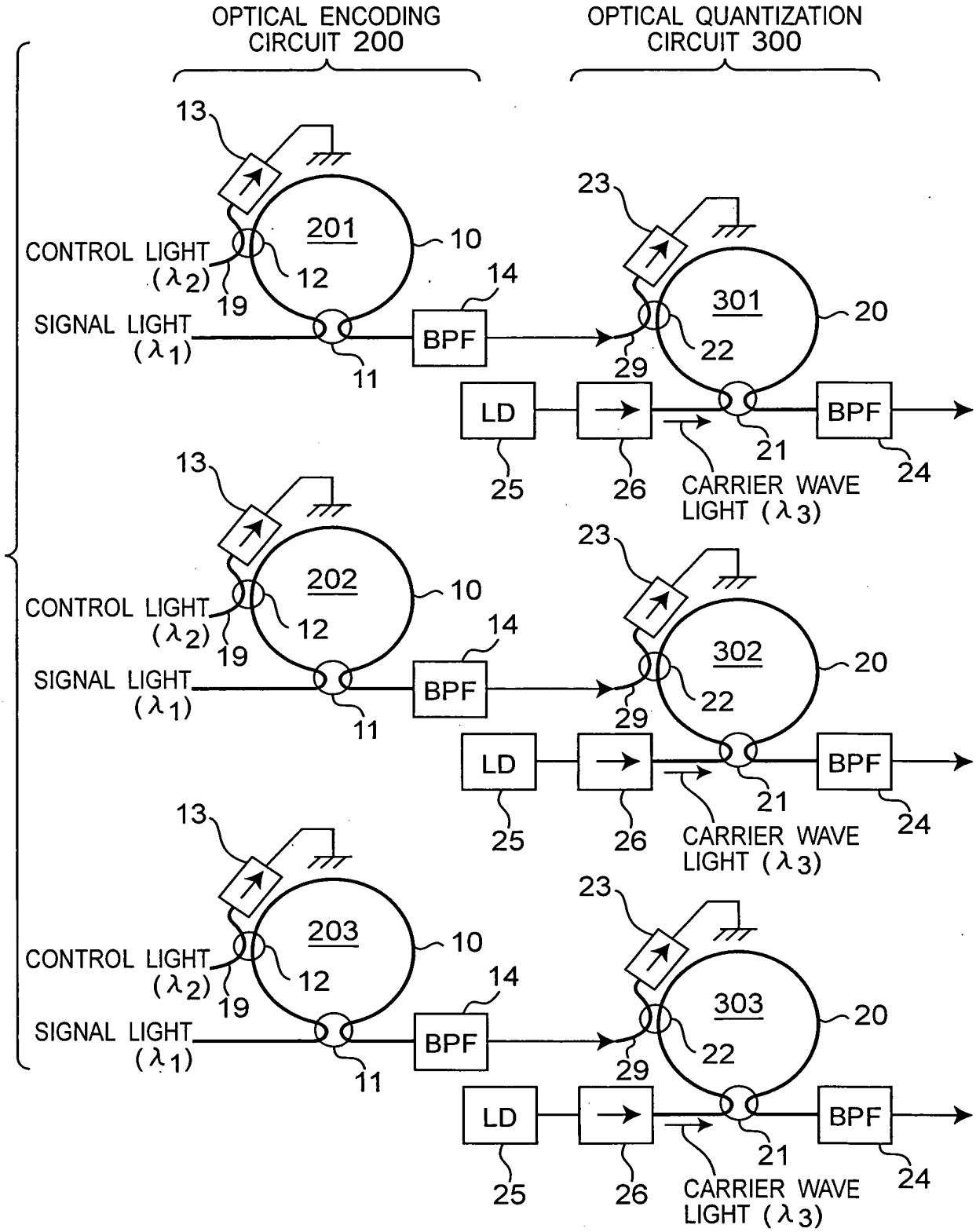

OPTICAL ENCODING CIRCUIT 200
OPTICAL QUANTIZATION CIRCUIT 300
13
201
10
CONTROL LIGHT (λ2)
19
12
14
SIGNAL LIGHT (λ1)
BPF
11
23
301
20
22
29
LD
BPF
21
25
26
CARRIER WAVE LIGHT (λ3)
24
202
303

Fig.9

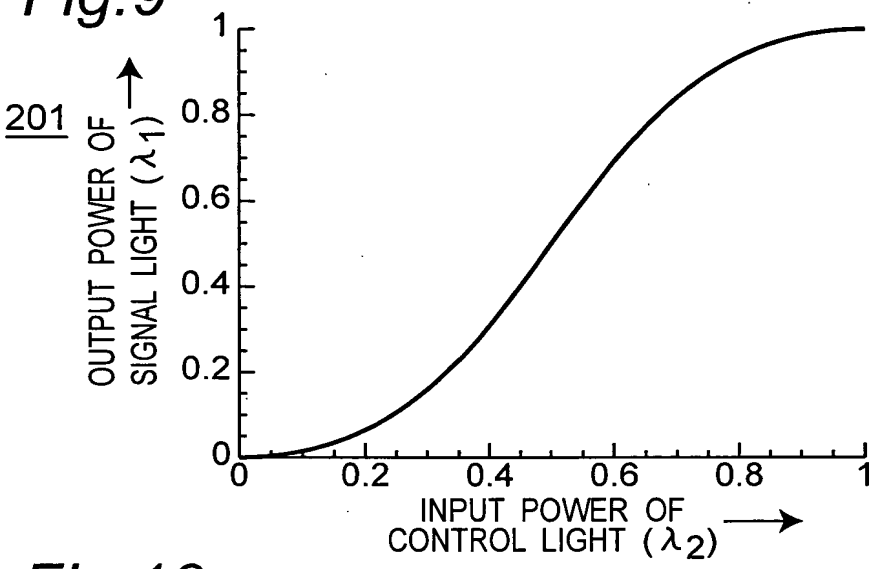


Fig.10

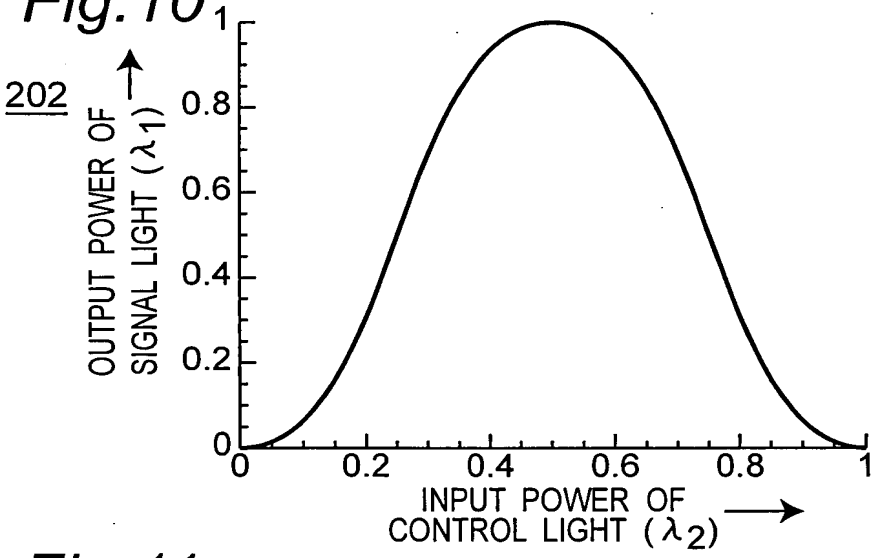


Fig.11

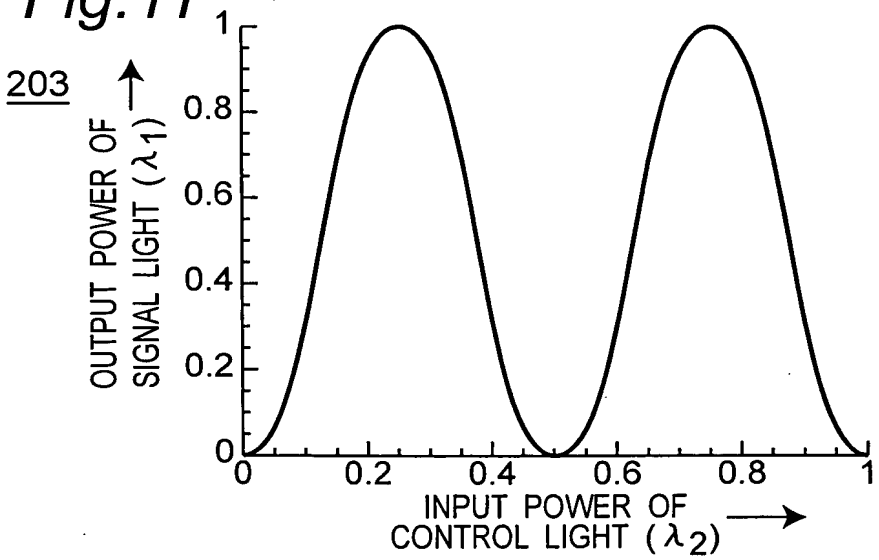


Fig.12

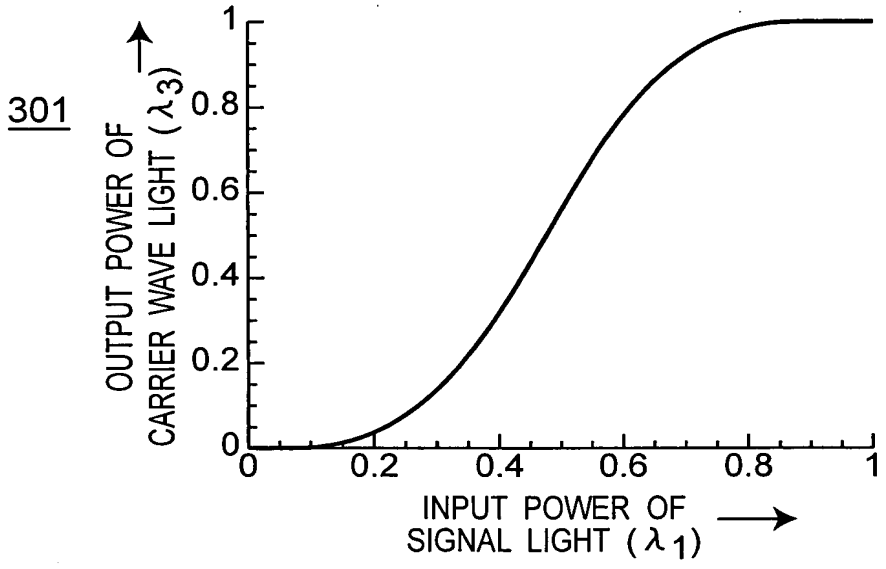

301
OUTPUT POWER OF CARRIER WAVE LIGHT (λ_3)
0
0.2
0.4
0.6
0.8
1
INPUT POWER OF SIGNAL LIGHT (λ_1)

Fig.13

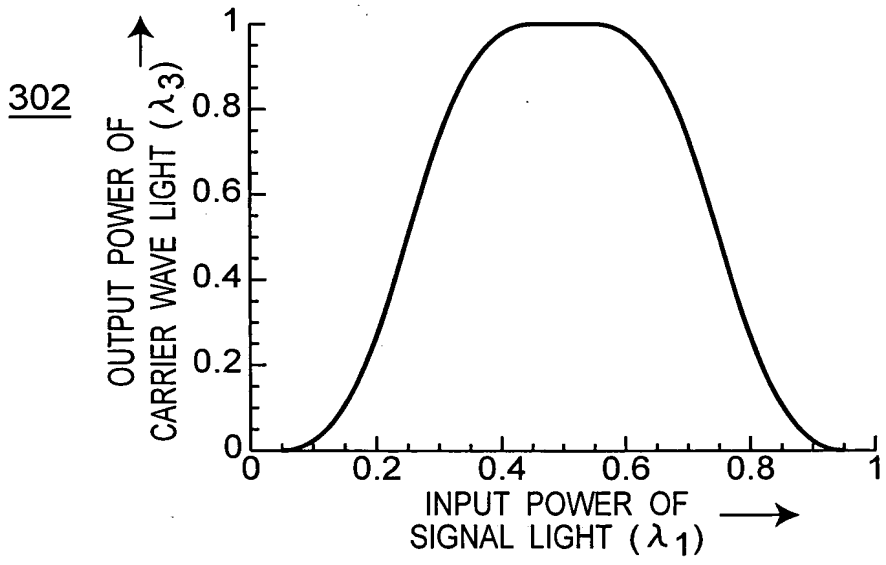

302
OUTPUT POWER OF CARRIER WAVE LIGHT (λ_3)
0
0.2
0.4
0.6
0.8
1
INPUT POWER OF SIGNAL LIGHT (λ_1)

Fig.14

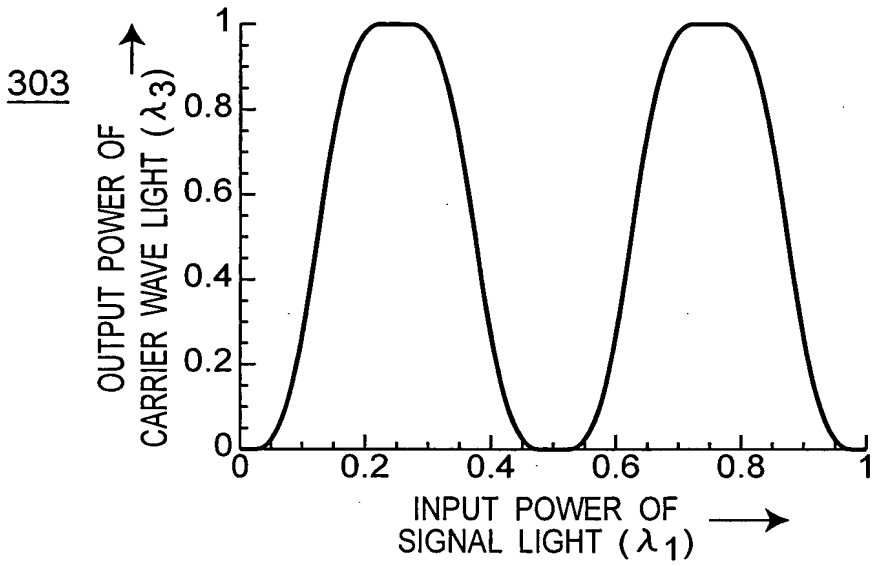

303
OUTPUT POWER OF CARRIER WAVE LIGHT (λ_3)
0
0.2
0.4
0.6
0.8
1
INPUT POWER OF SIGNAL LIGHT (λ_1)

Fig.15

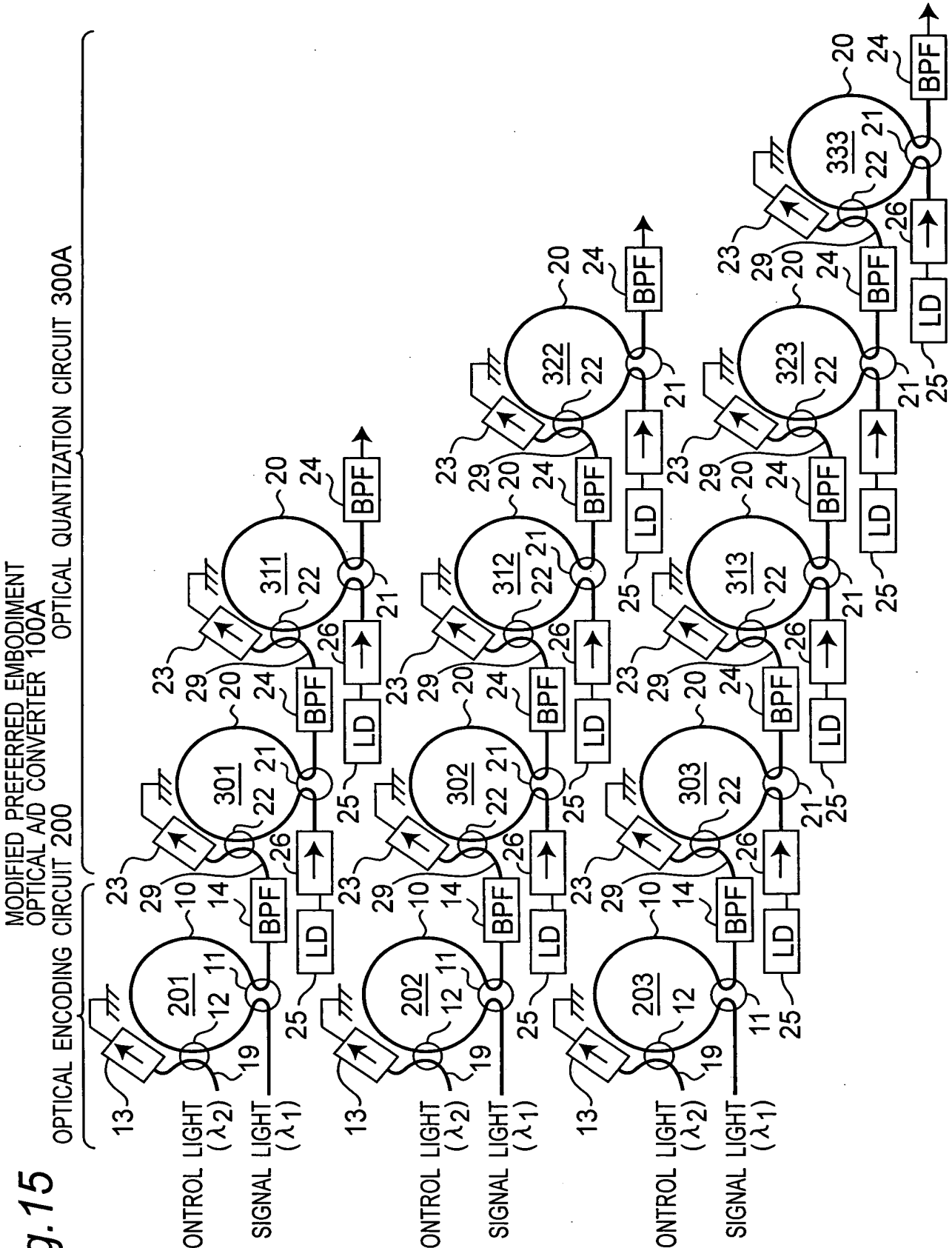

MODIFIED PREFERRED EMBODIMENT
OPTICAL A/D CONVERTER 100A
OPTICAL ENCODING CIRCUIT 200
OPTICAL QUANTIZATION CIRCUIT 300A
CONTROL LIGHT (λ2)
SIGNAL LIGHT (λ1)
LD
BPF
201
202
203
301
302
303
311
312
313
322
323
333

Fig.16

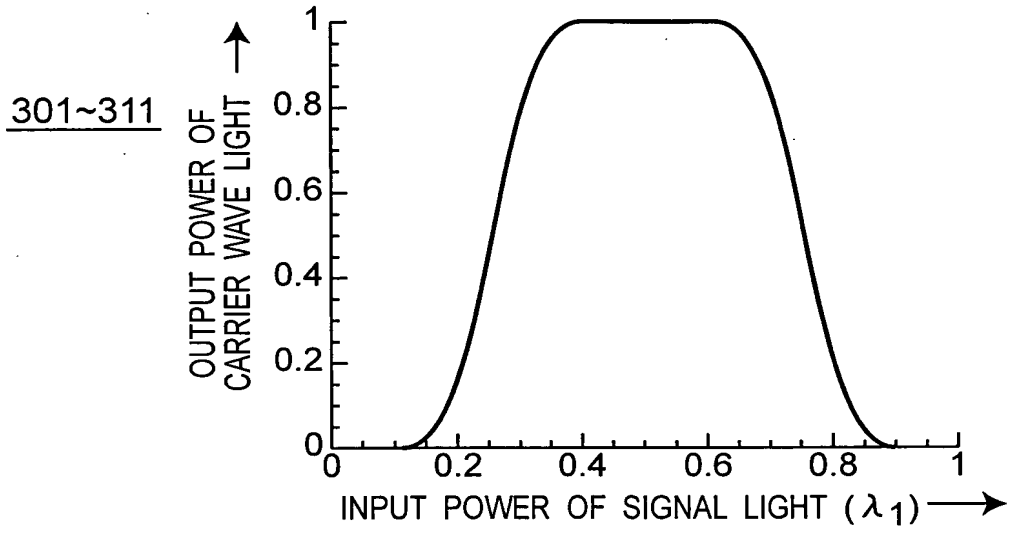

301~311
OUTPUT POWER OF CARRIER WAVE LIGHT
0
0.2
0.4
0.6
0.8
1
INPUT POWER OF SIGNAL LIGHT (λ1)

Fig.17

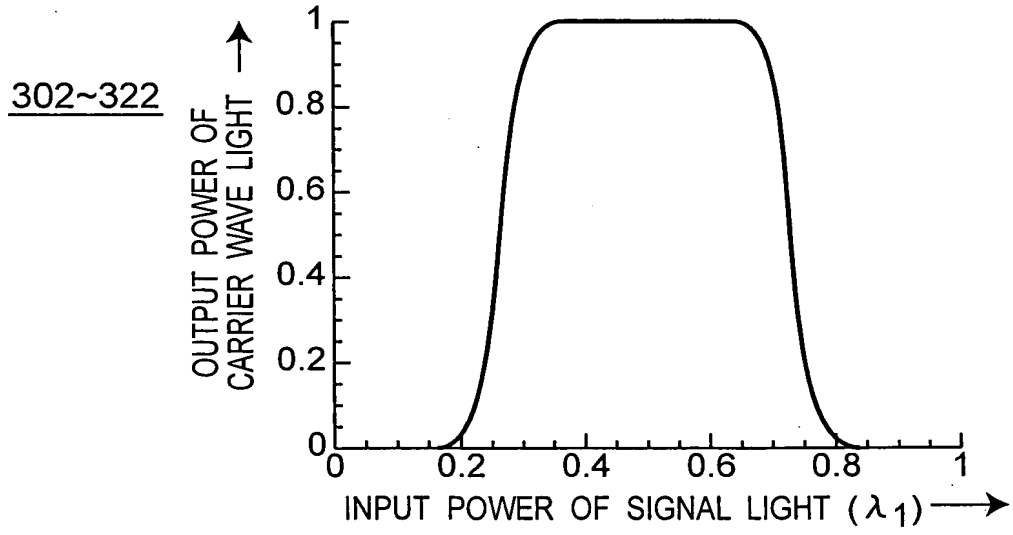
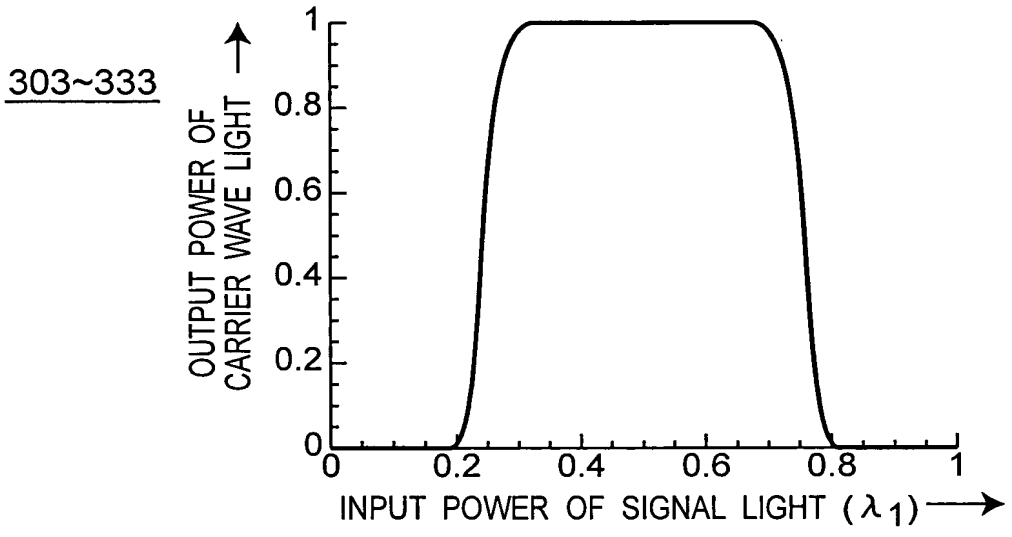

302~322
OUTPUT POWER OF CARRIER WAVE LIGHT
0
0.2
0.4
0.6
0.8
1
INPUT POWER OF SIGNAL LIGHT (λ1)

Fig.18


303~333
OUTPUT POWER OF CARRIER WAVE LIGHT
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
INPUT POWER OF SIGNAL LIGHT (λ1)

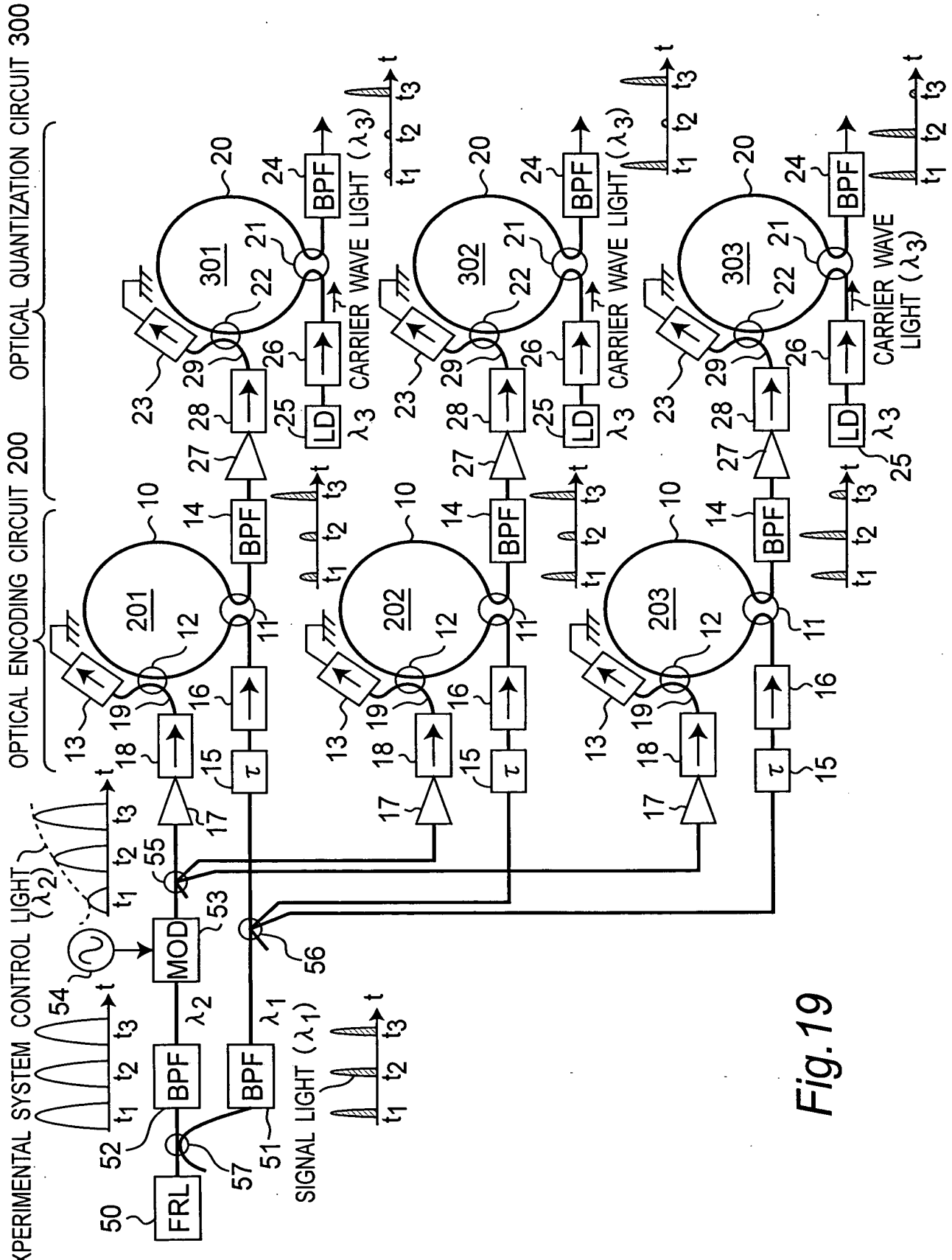

EXPERIMENTAL SYSTEM CONTROL LIGHT
OPTICAL ENCODING CIRCUIT 200
OPTICAL QUANTIZATION CIRCUIT 300
SIGNAL LIGHT (λ1)
CARRIER WAVE LIGHT (λ3)
FRL
MOD
BPF
LD
τ
201
202
203
301
302
303

Fig.19

Fig.20

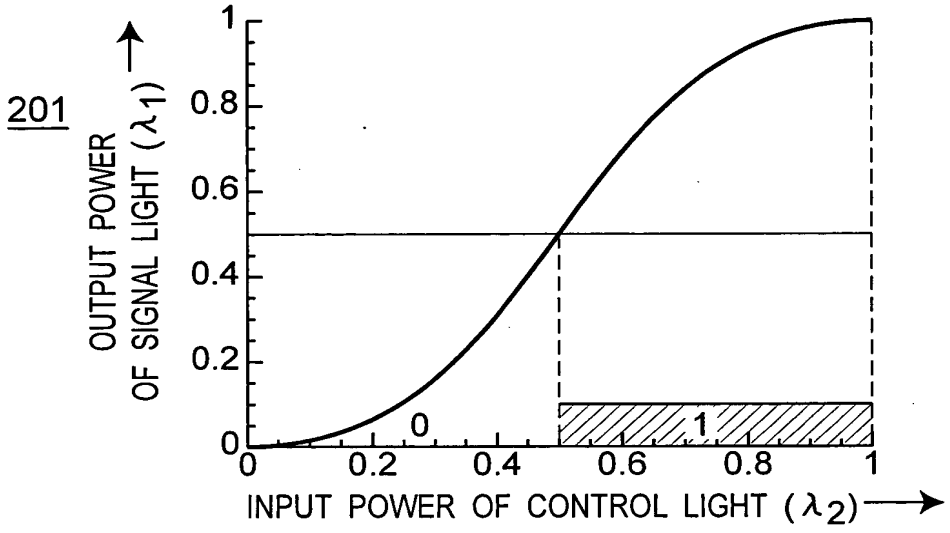

201
OUTPUT POWER OF SIGNAL LIGHT (λ_1)
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
0
1
INPUT POWER OF CONTROL LIGHT (λ_2)

Fig.21

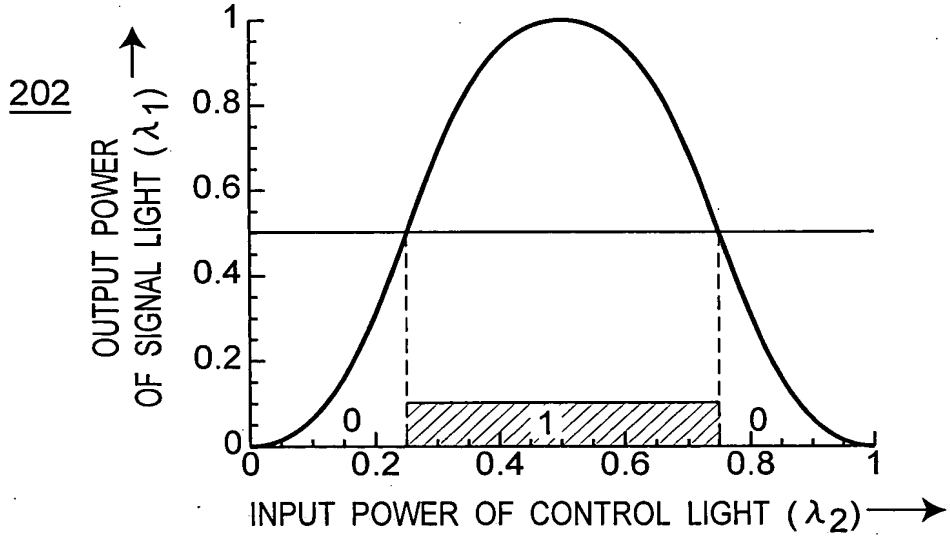
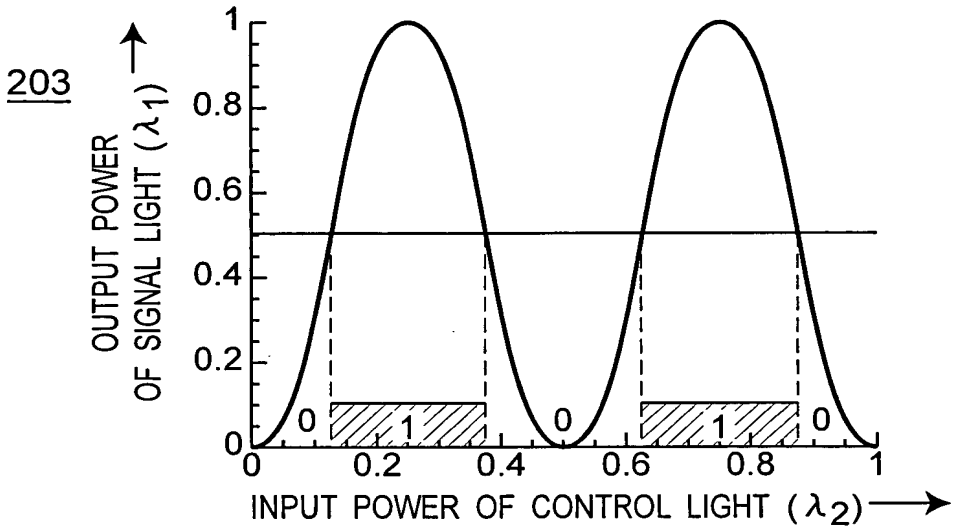

202
OUTPUT POWER OF SIGNAL LIGHT (λ_1)
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
0
1
0
INPUT POWER OF CONTROL LIGHT (λ_2)

Fig.22


203
OUTPUT POWER OF SIGNAL LIGHT (λ_1)
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
INPUT POWER OF CONTROL LIGHT (λ_2)
0
1
0
1
0

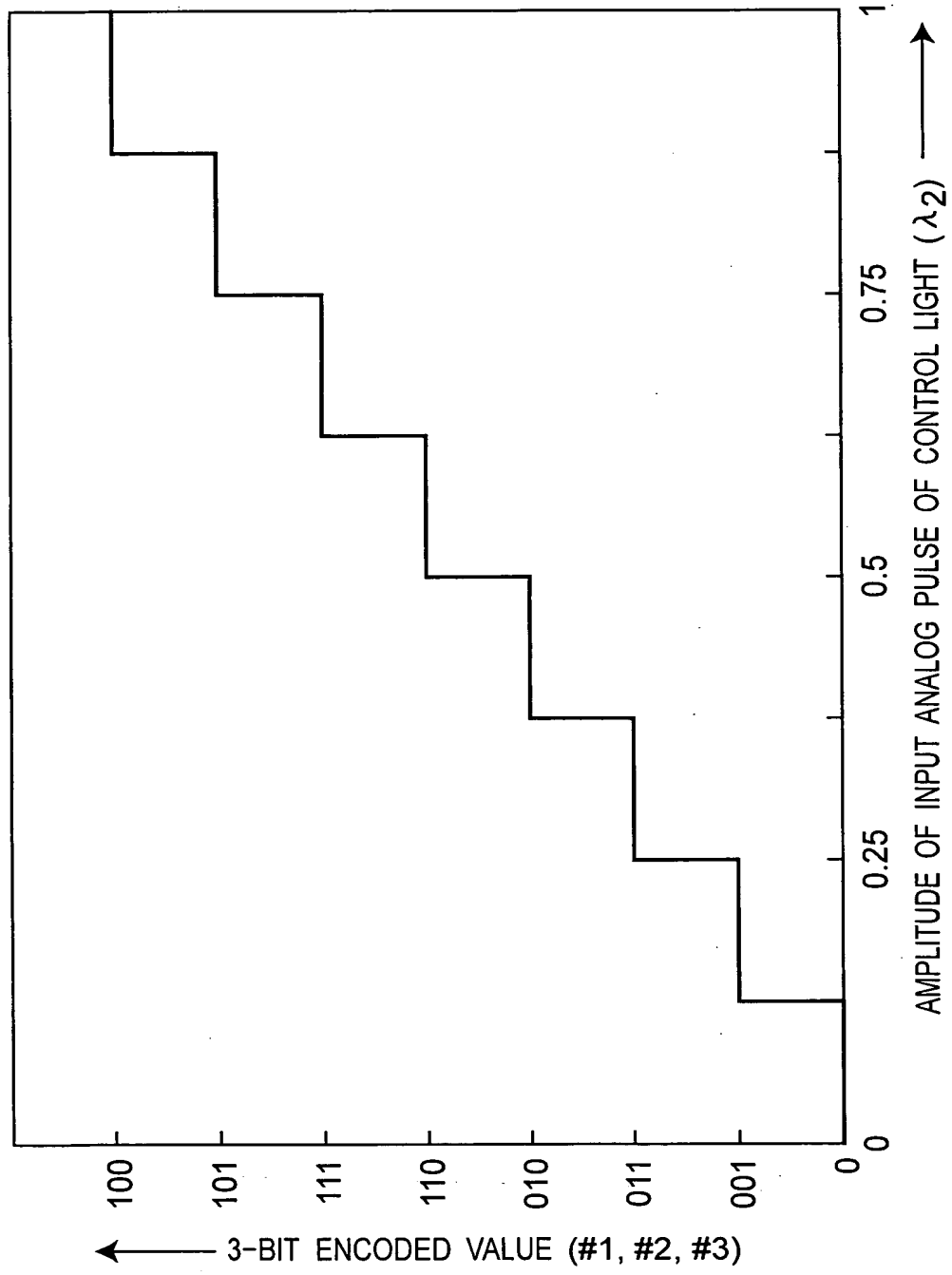

100
101
111
110
010
011
001
0
3-BIT ENCODED VALUE (#1, #2, #3)
0
0.25
0.5
0.75
1
AMPLITUDE OF INPUT ANALOG PULSE OF CONTROL LIGHT (λ2)

Fig.23

Fig.24

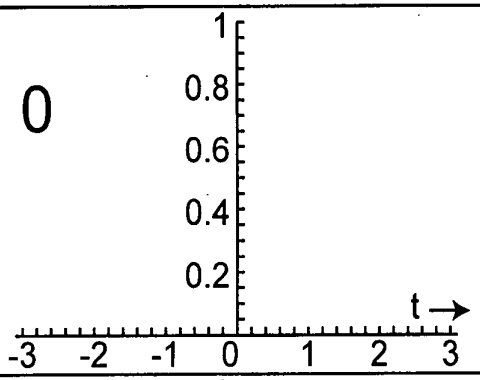
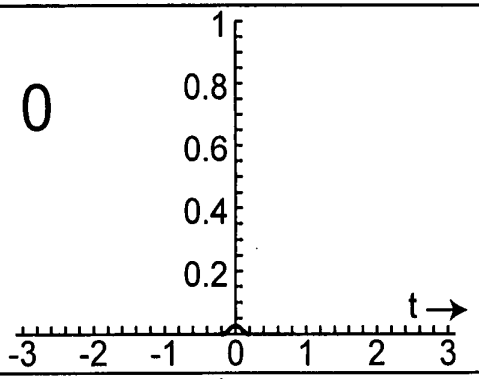
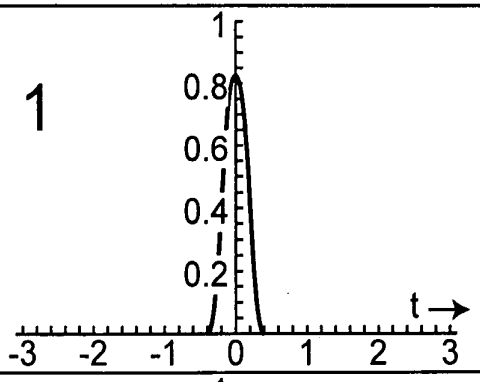
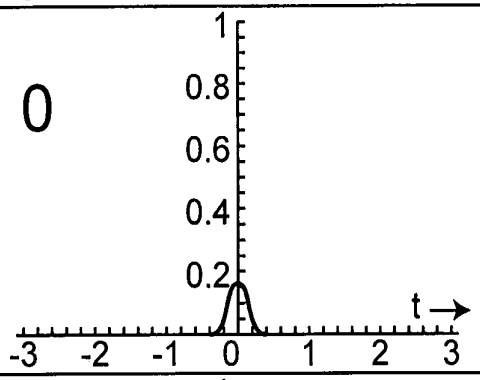
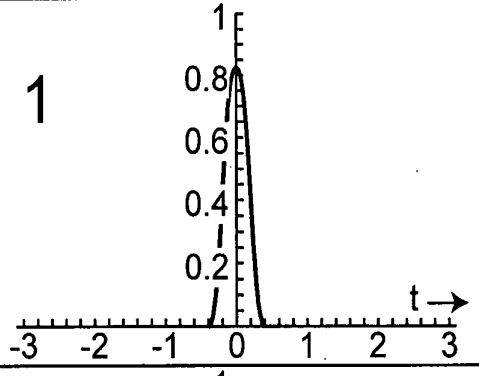
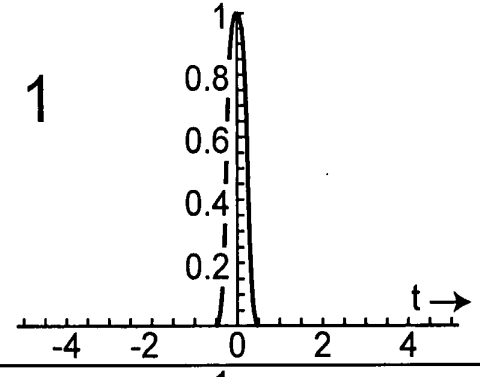
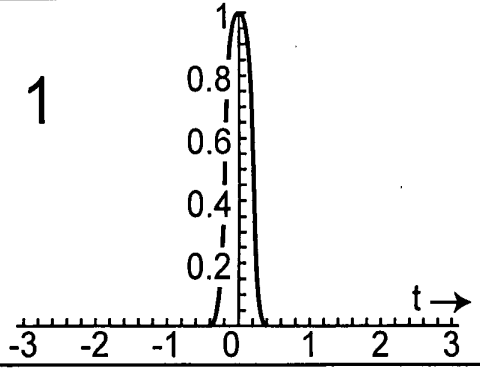
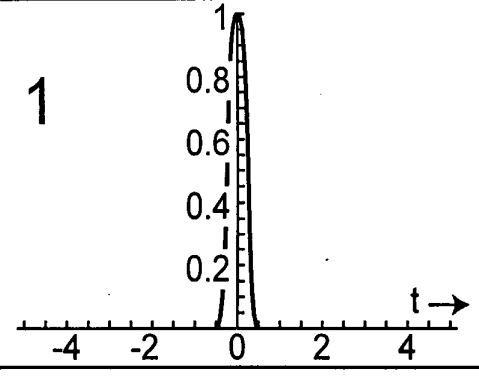
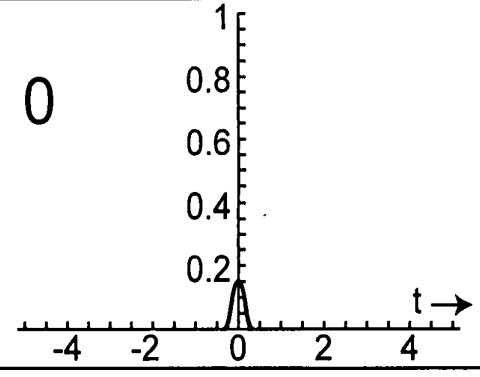
	AMPLITUDE OF ANALOG PULSE AFTER PROCESSING BY SINGLE OPTICAL THRESHOLD PROCESSOR IS 0.2	AMPLITUDE OF ANALOG PULSE AFTER PROCESSING BY SINGLE OPTICAL THRESHOLD PROCESSOR IS 0.3	AMPLITUDE OF ANALOG PULSE AFTER PROCESSING BY SINGLE OPTICAL THRESHOLD PROCESSOR IS 0.6
ENCODED VALUE #1			
ENCODED VALUE #2			
ENCODED VALUE #3			

Fig.25

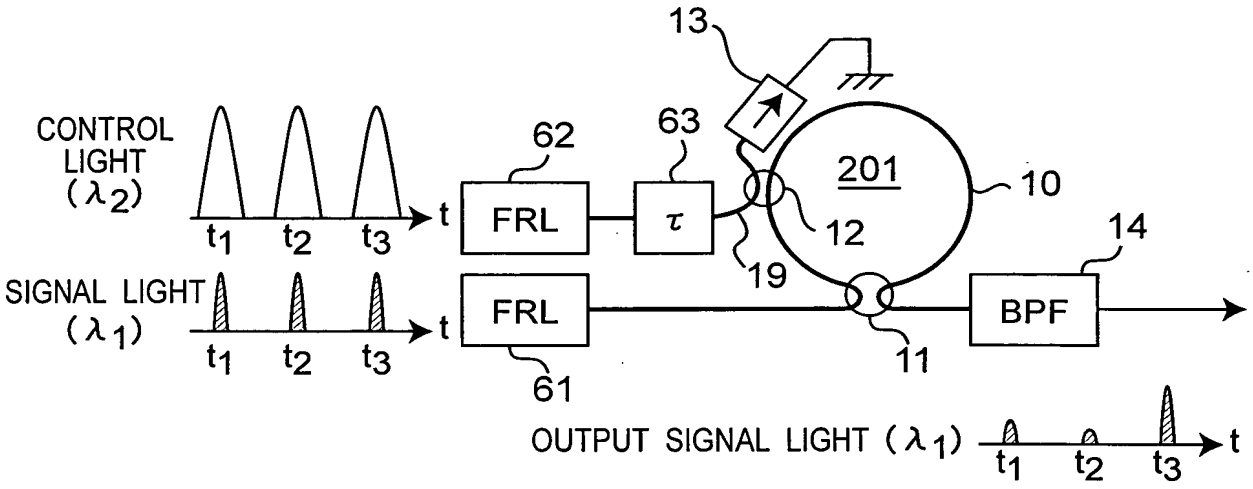

13
CONTROL LIGHT (λ2)
62
63
201
10
FRL
τ
12
14
SIGNAL LIGHT (λ1)
19
FRL
BPF
t1 t2 t3
t
11
61
OUTPUT SIGNAL LIGHT (λ1)

Fig.26

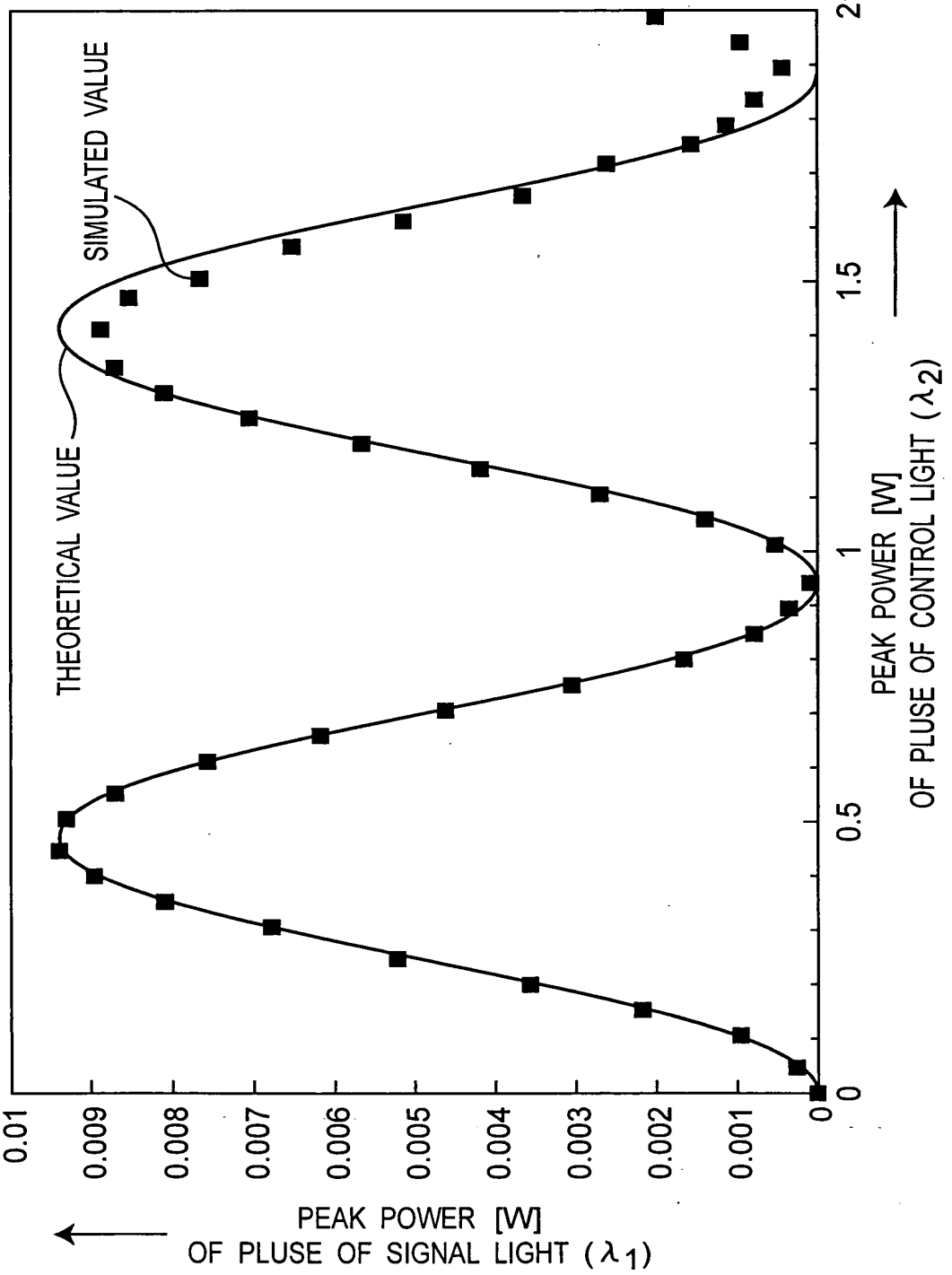

THEORETICAL VALUE
SIMULATED VALUE
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0
0.5
1
1.5
2
PEAK POWER [W]
OF PLUSE OF SIGNAL LIGHT (λ1)
PEAK POWER [W]
OF PLUSE OF CONTROL LIGHT (λ2)

Fig.27

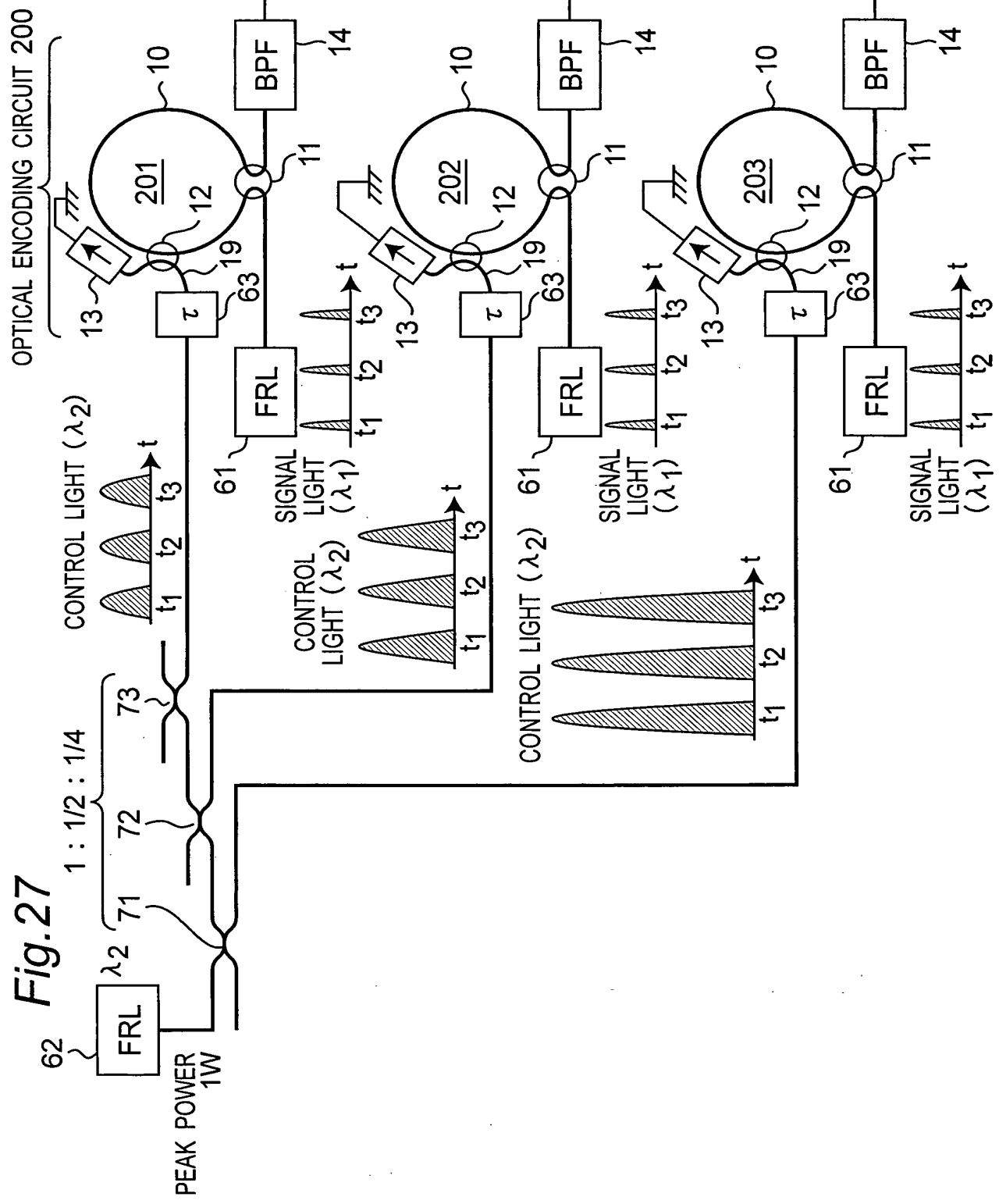

OPTICAL ENCODING CIRCUIT 200
PEAK POWER 1W
62
FRL
λ2
71
72
73
1 : 1/2 : 1/4
CONTROL LIGHT (λ2)
t1 t2 t3 t
201
202
203
10
11
12
13
19
63
τ
FRL
61
SIGNAL LIGHT (λ1)
BPF
14

Fig.28

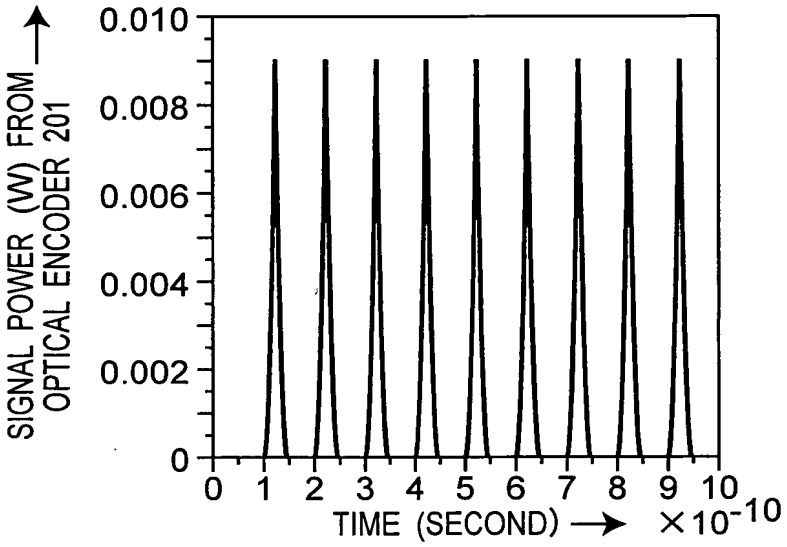

SIGNAL POWER (W) FROM OPTICAL ENCODER 201
0.010
0.008
0.006
0.004
0.002
0
0 1 2 3 4 5 6 7 8 9 10
TIME (SECOND) → ×10-10

Fig.29

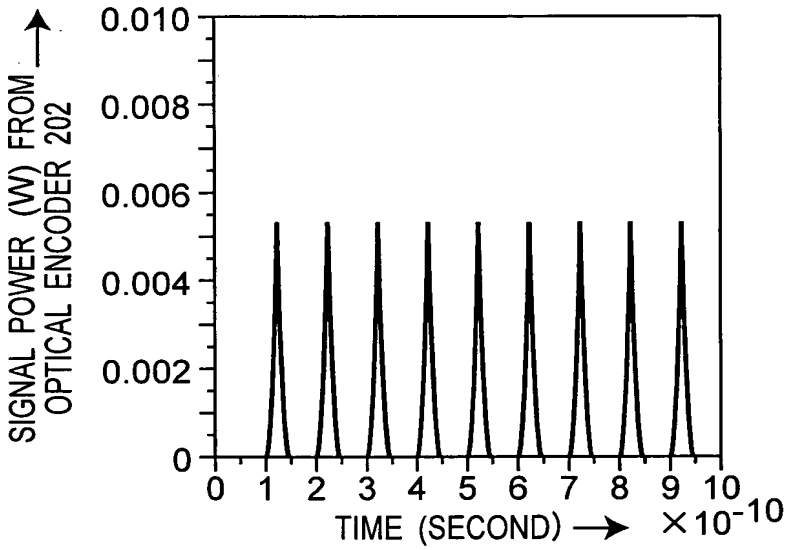

SIGNAL POWER (W) FROM OPTICAL ENCODER 202
0.010
0.008
0.006
0.004
0.002
0
0 1 2 3 4 5 6 7 8 9 10
TIME (SECOND) → ×10-10

Fig.30

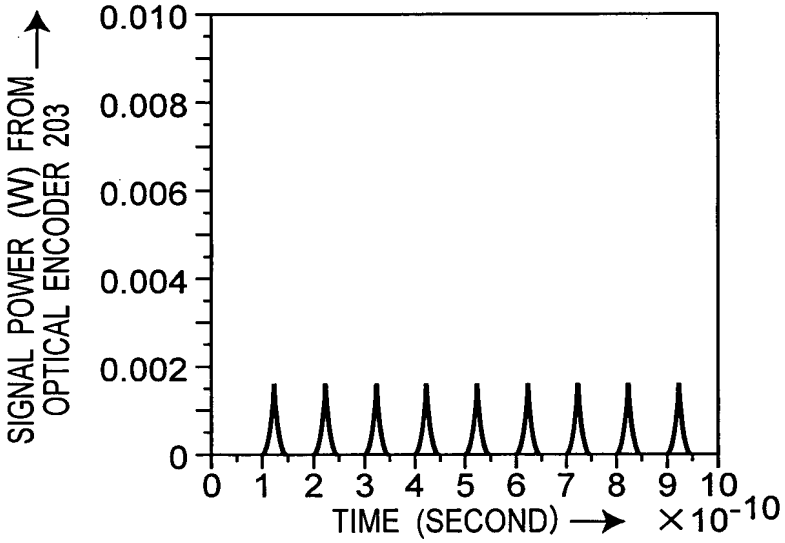

SIGNAL POWER (W) FROM OPTICAL ENCODER 203
0.010
0.008
0.006
0.004
0.002
0
0 1 2 3 4 5 6 7 8 9 10
TIME (SECOND) → ×10-10

Fig.31

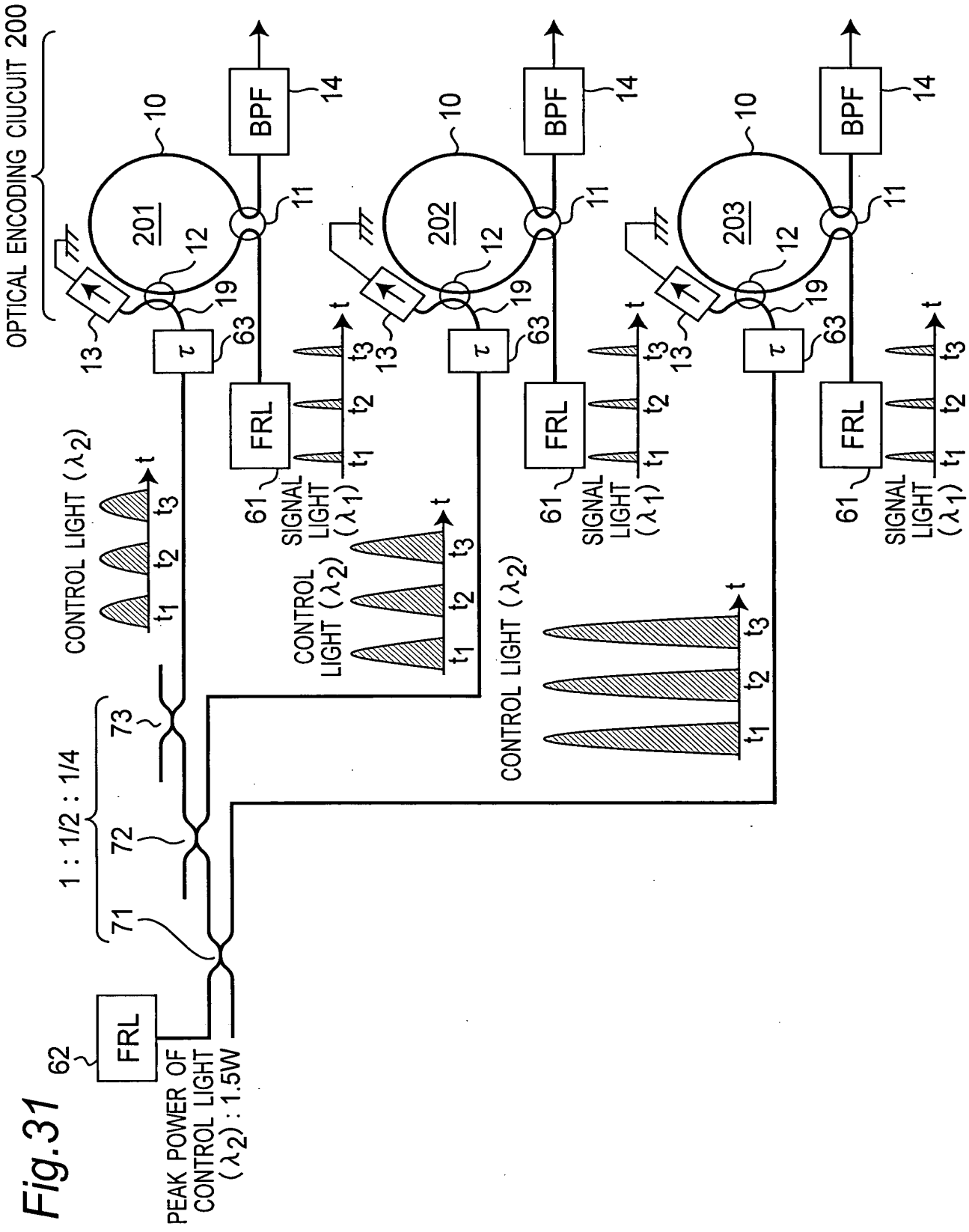

OPTICAL ENCODING CIUCUIT 200
62
FRL
PEAK POWER OF CONTROL LIGHT (λ_2) : 1.5W
1 : 1/2 : 1/4
71
72
73
CONTROL LIGHT (λ_2)
t_1 t_2 t_3 t
201
202
203
10
11
12
13
19
63
τ
FRL
61
SIGNAL LIGHT (λ_1)
BPF
14

Fig.32

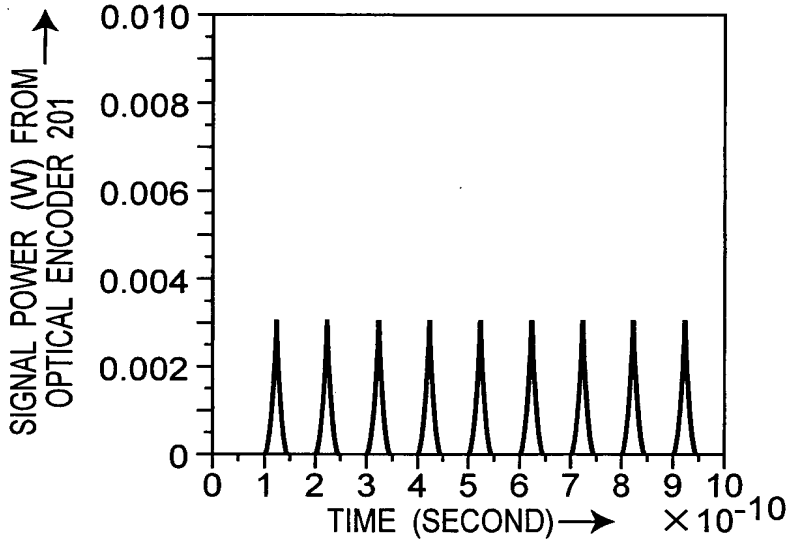

SIGNAL POWER (W) FROM OPTICAL ENCODER 201
0.010
0.008
0.006
0.004
0.002
0
0 1 2 3 4 5 6 7 8 9 10
TIME (SECOND)
×10-10

Fig.33

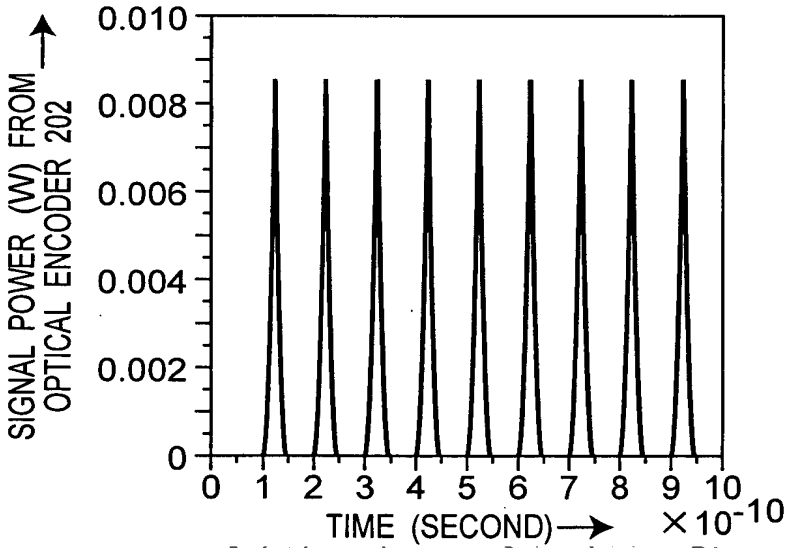
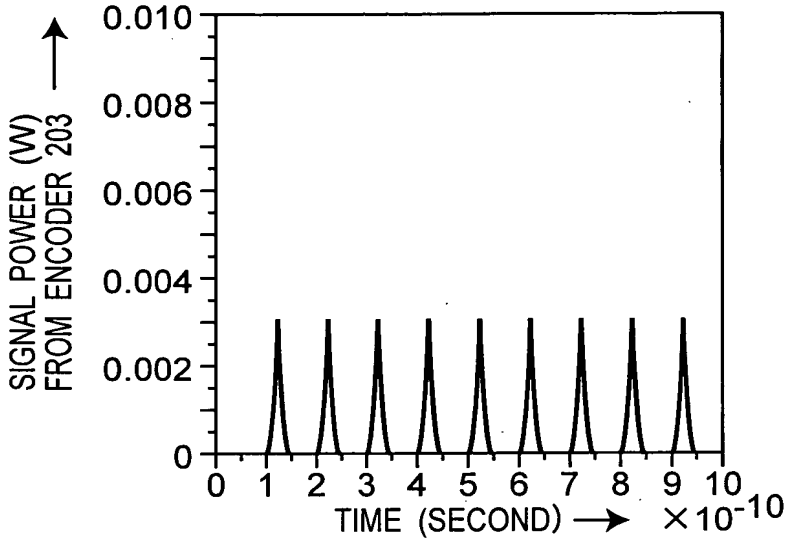

SIGNAL POWER (W) FROM OPTICAL ENCODER 202
0.010
0.008
0.006
0.004
0.002
0
0 1 2 3 4 5 6 7 8 9 10
TIME (SECOND)
×10-10

Fig.34


SIGNAL POWER (W)
FROM ENCODER 203
0.010
0.008
0.006
0.004
0.002
0
0 1 2 3 4 5 6 7 8 9 10
TIME (SECOND) → ×10-10

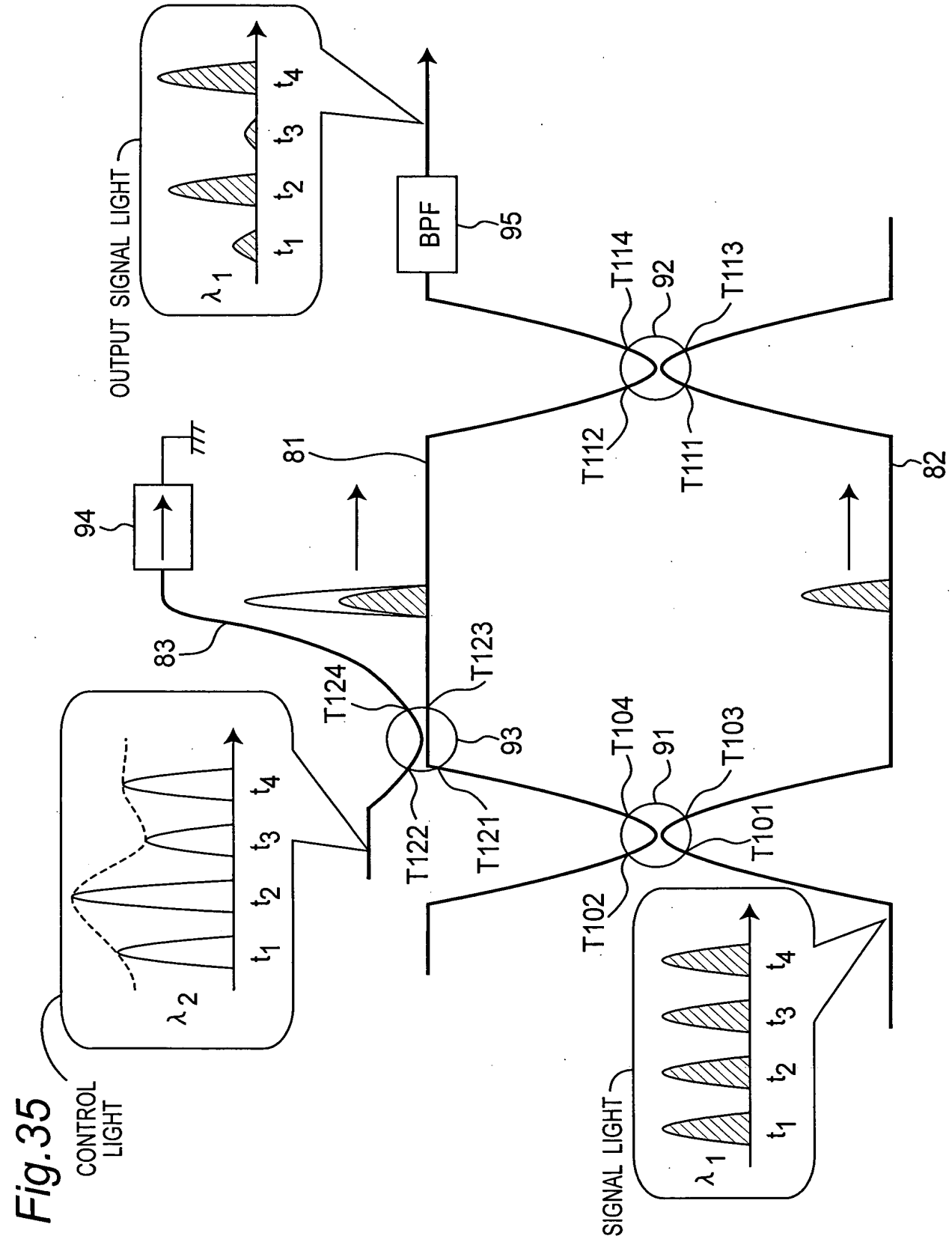

CONTROL LIGHT
SIGNAL LIGHT
OUTPUT SIGNAL LIGHT
BPF
95
94
81
82
83
91
92
93
T101
T102
T103
T104
T111
T112
T113
T114
T121
T122
T123
T124
λ1
λ2
t1
t2
t3
t4

Fig.35

Fig.36

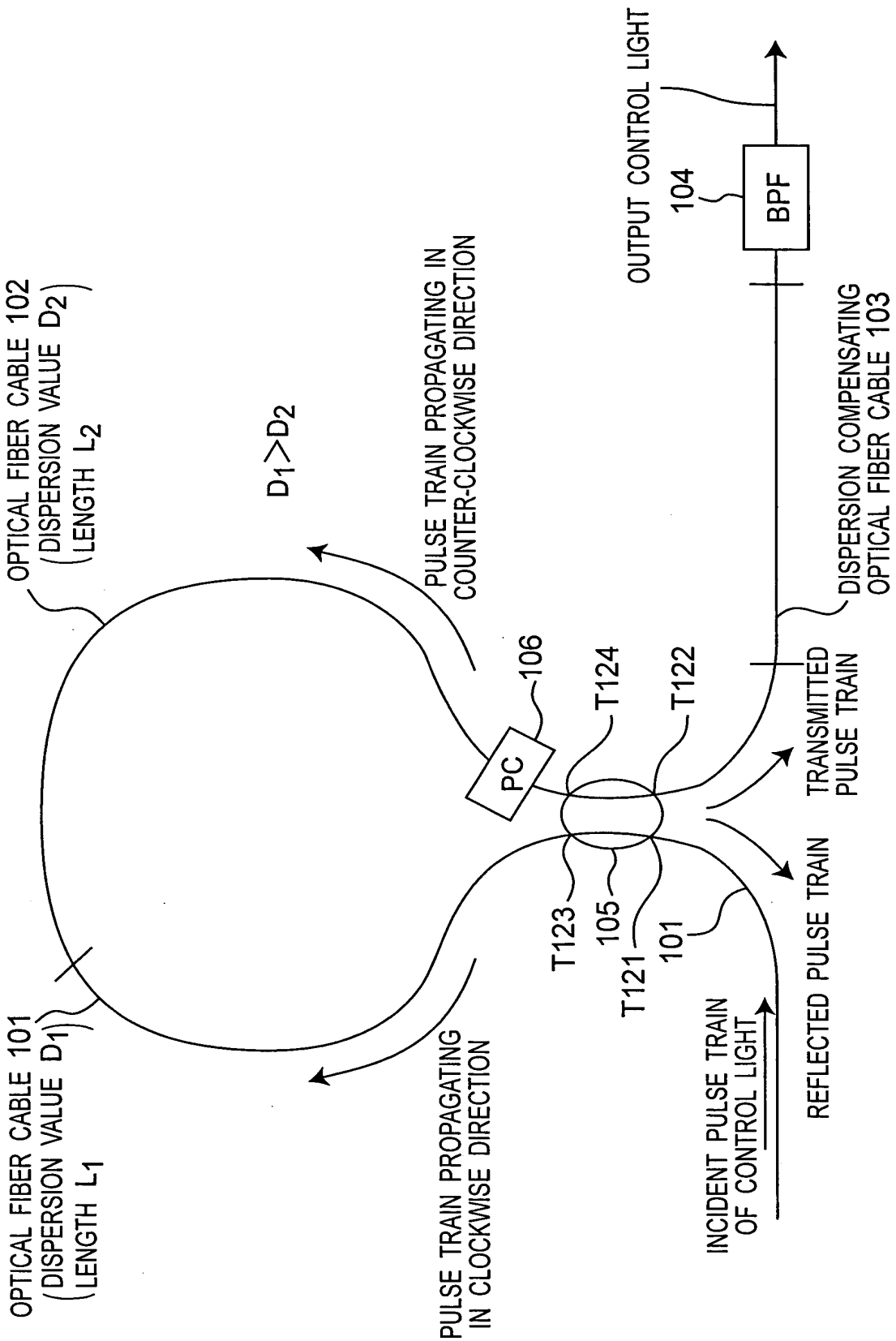

OPTICAL FIBER CABLE 101
(DISPERSION VALUE D1)
(LENGTH L1
OPTICAL FIBER CABLE 102
(DISPERSION VALUE D2)
(LENGTH L2
D1>D2
PULSE TRAIN PROPAGATING IN
COUNTER-CLOCKWISE DIRECTION
PULSE TRAIN PROPAGATING
IN CLOCKWISE DIRECTION
OUTPUT CONTROL LIGHT
104
BPF
DISPERSION COMPENSATING
OPTICAL FIBER CABLE 103
106
PC
T124
T122
T123
105
T121
101
TRANSMITTED
PULSE TRAIN
REFLECTED PULSE TRAIN
INCIDENT PULSE TRAIN
OF CONTROL LIGHT

Fig.37

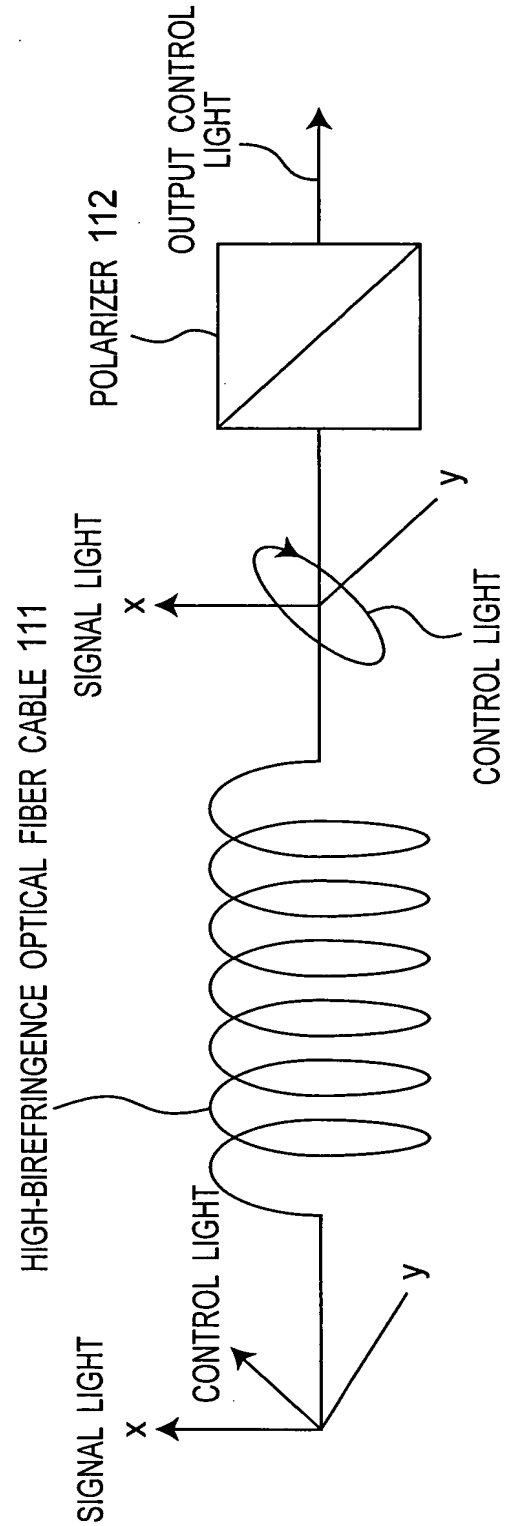
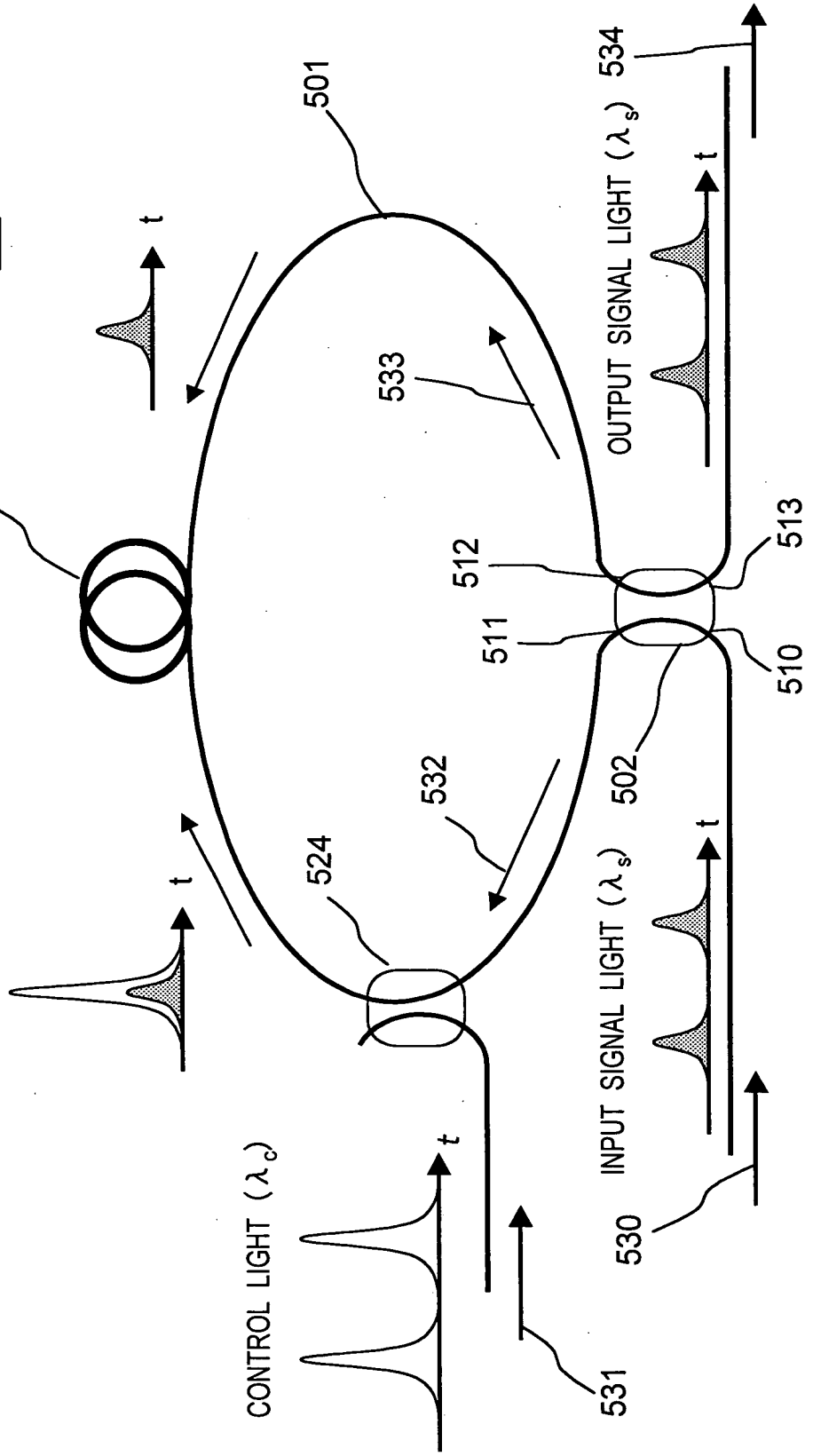

OUTPUT CONTROL LIGHT
POLARIZER 112
SIGNAL LIGHT
x
y
CONTROL LIGHT
HIGH-BIREFRINGENCE OPTICAL FIBER CABLE 111
SIGNAL LIGHT
x
CONTROL LIGHT
y

Fig.38


500
501
504
511
512
513
510
502
524
532
533
534
530
531
t
CONTROL LIGHT (λ_c)
INPUT SIGNAL LIGHT (λ_s)
OUTPUT SIGNAL LIGHT (λ_s)

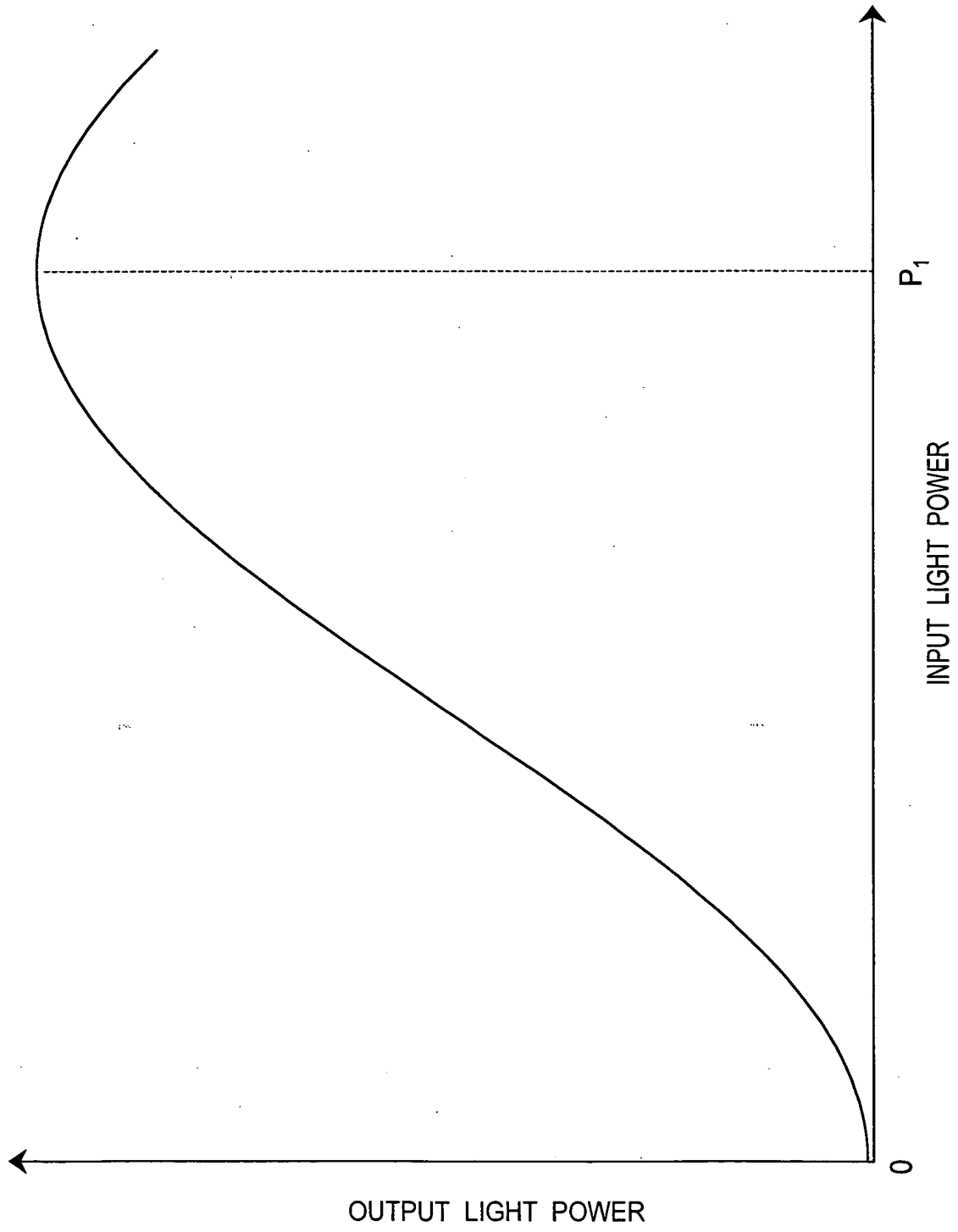


Fig.39

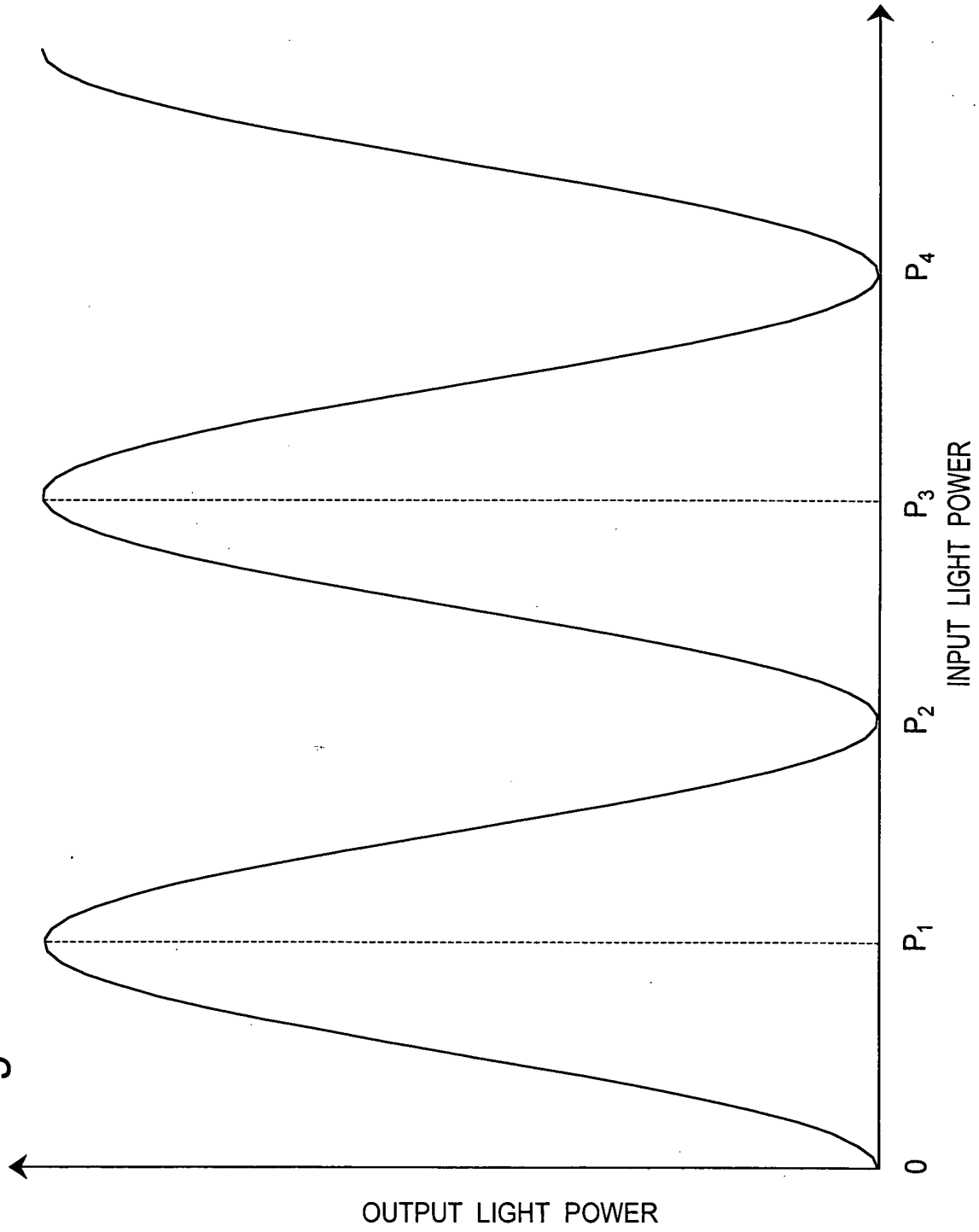


Fig.40

Fig.41

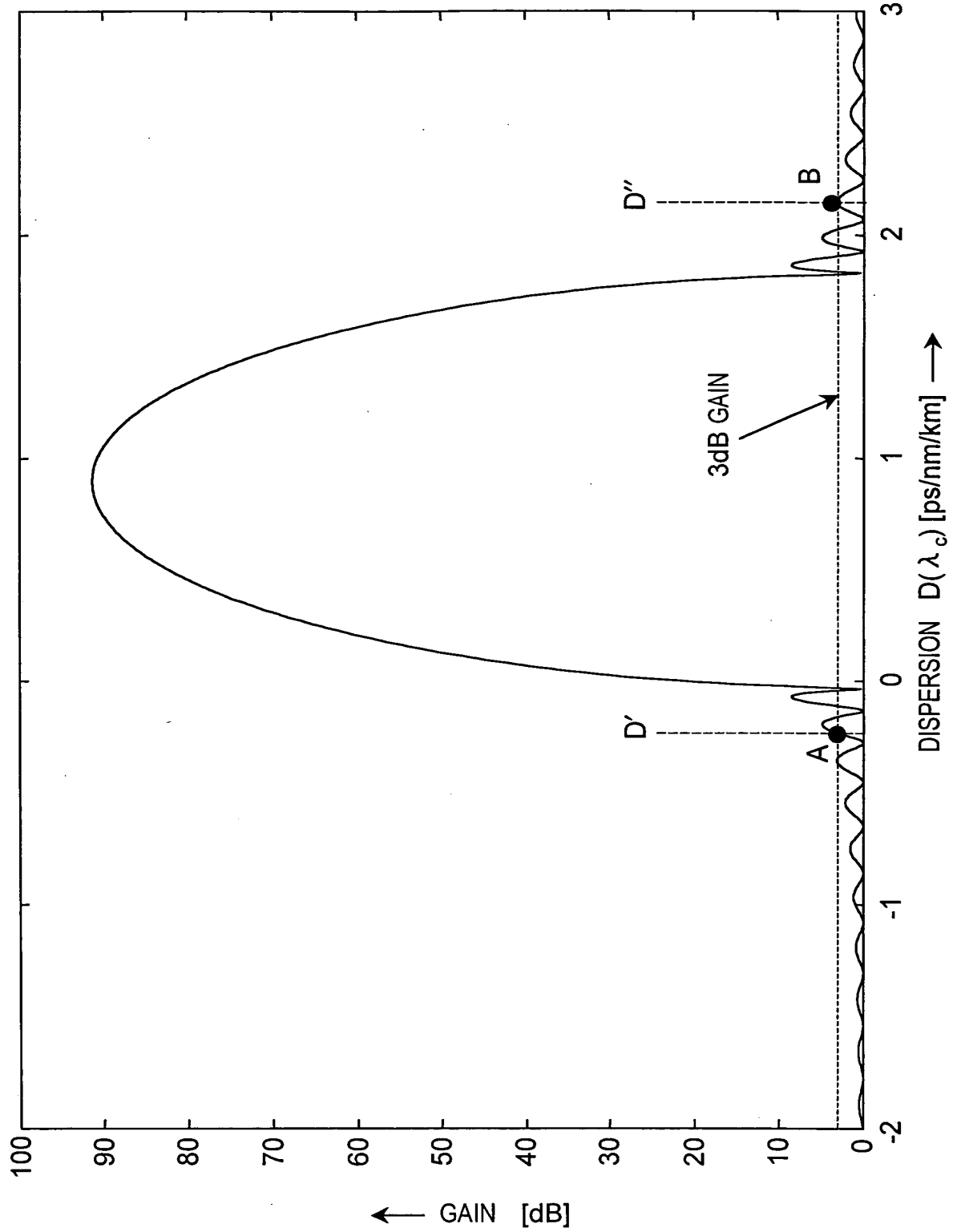

100
90
80
70
60
50
40
30
20
10
0
GAIN [dB]
-2
-1
0
1
2
3
DISPERSION D(λc) [ps/nm/km]
3dB GAIN
D′
D″
A
B

Fig.42

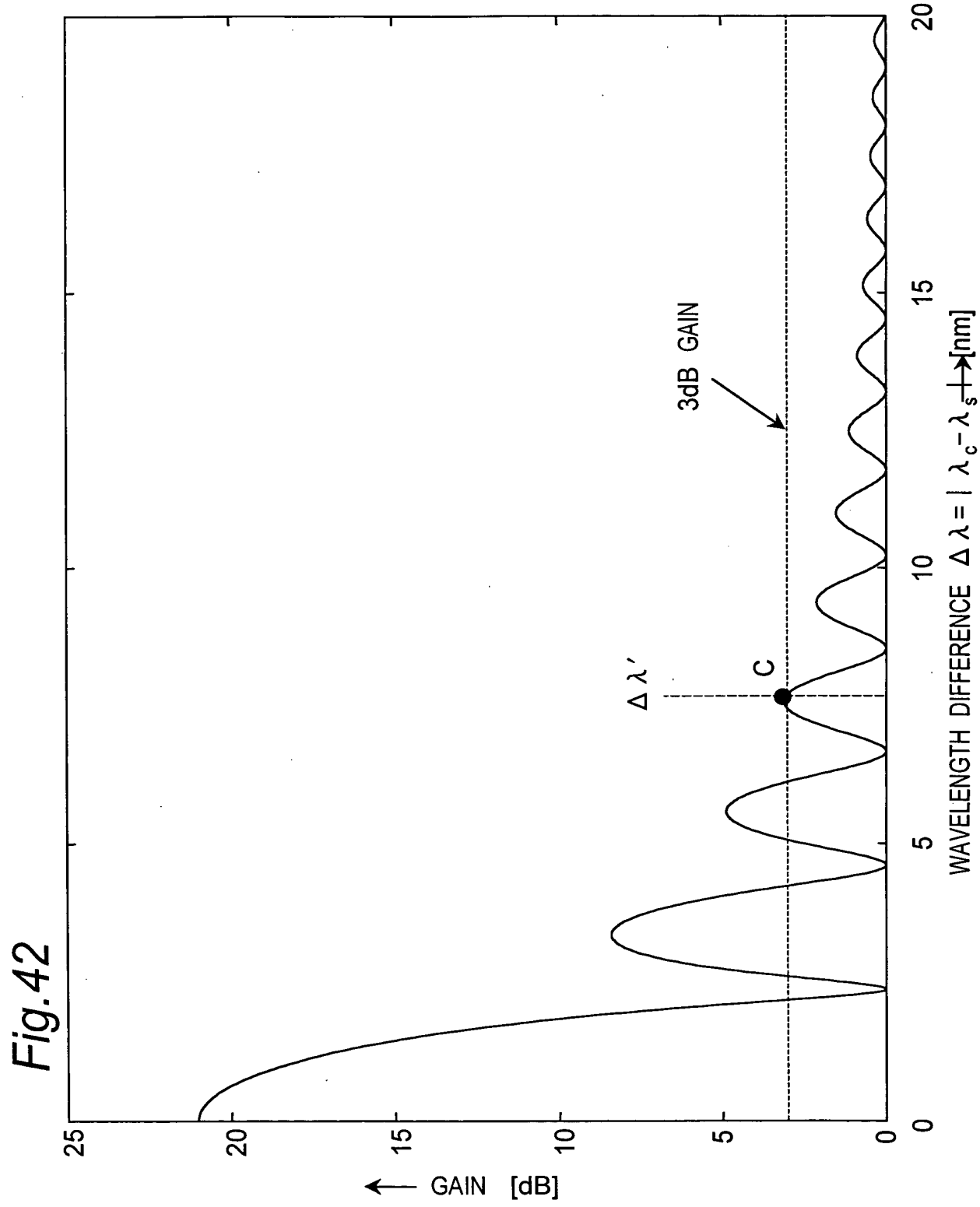

25
20
15
10
5
0
GAIN [dB]
0
5
10
15
20
WAVELENGTH DIFFERENCE Δλ = | λc − λs | [nm]
3dB GAIN
C
Δλ'

Fig.43

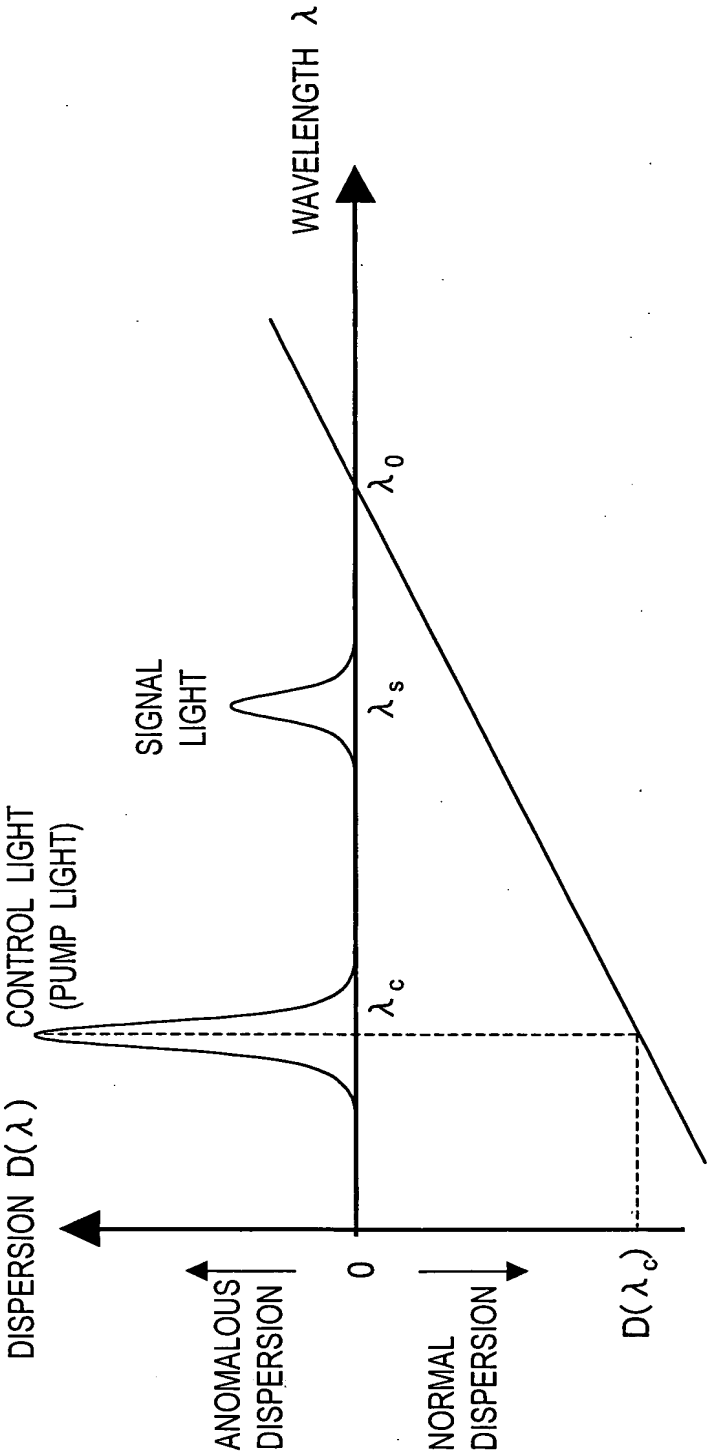

DISPERSION D(λ)
WAVELENGTH λ
CONTROL LIGHT
(PUMP LIGHT)
SIGNAL
LIGHT
λc
λs
λ0
ANOMALOUS
DISPERSION
0
NORMAL
DISPERSION
D(λc)

Fig.44

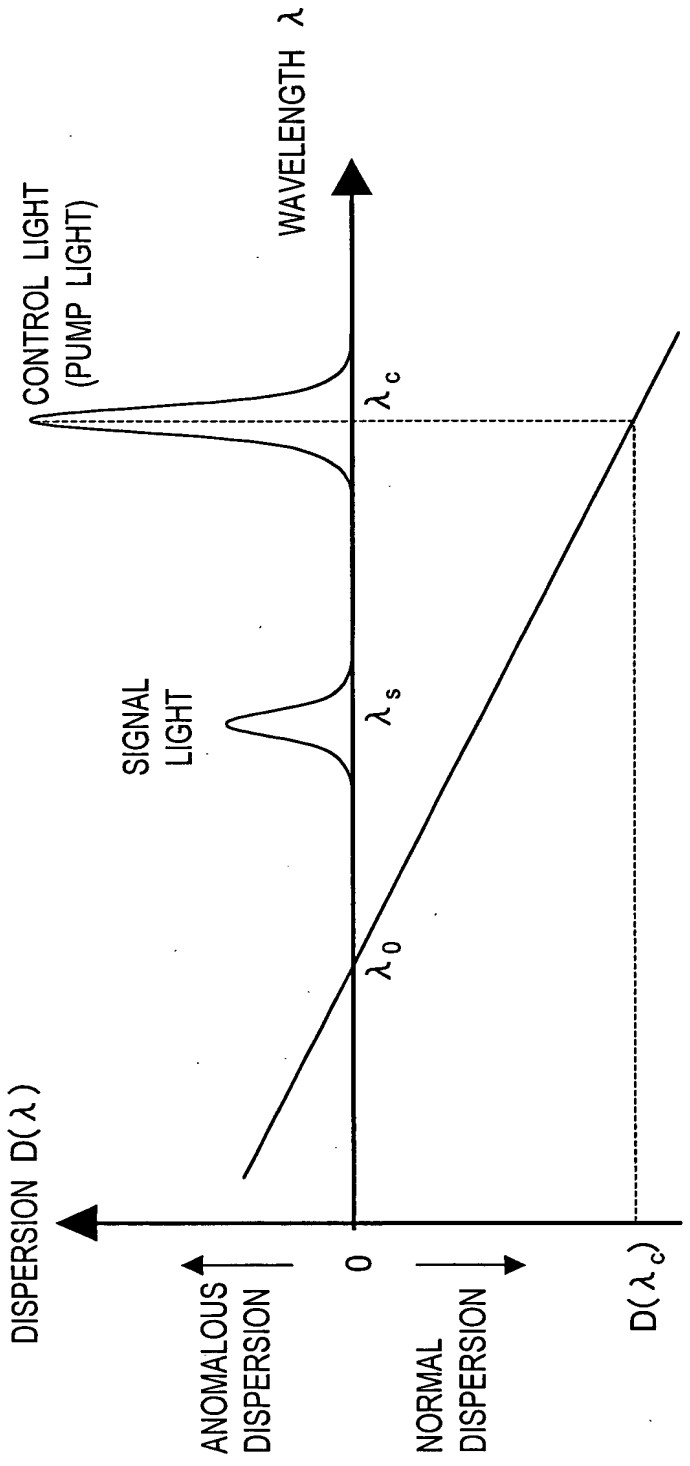
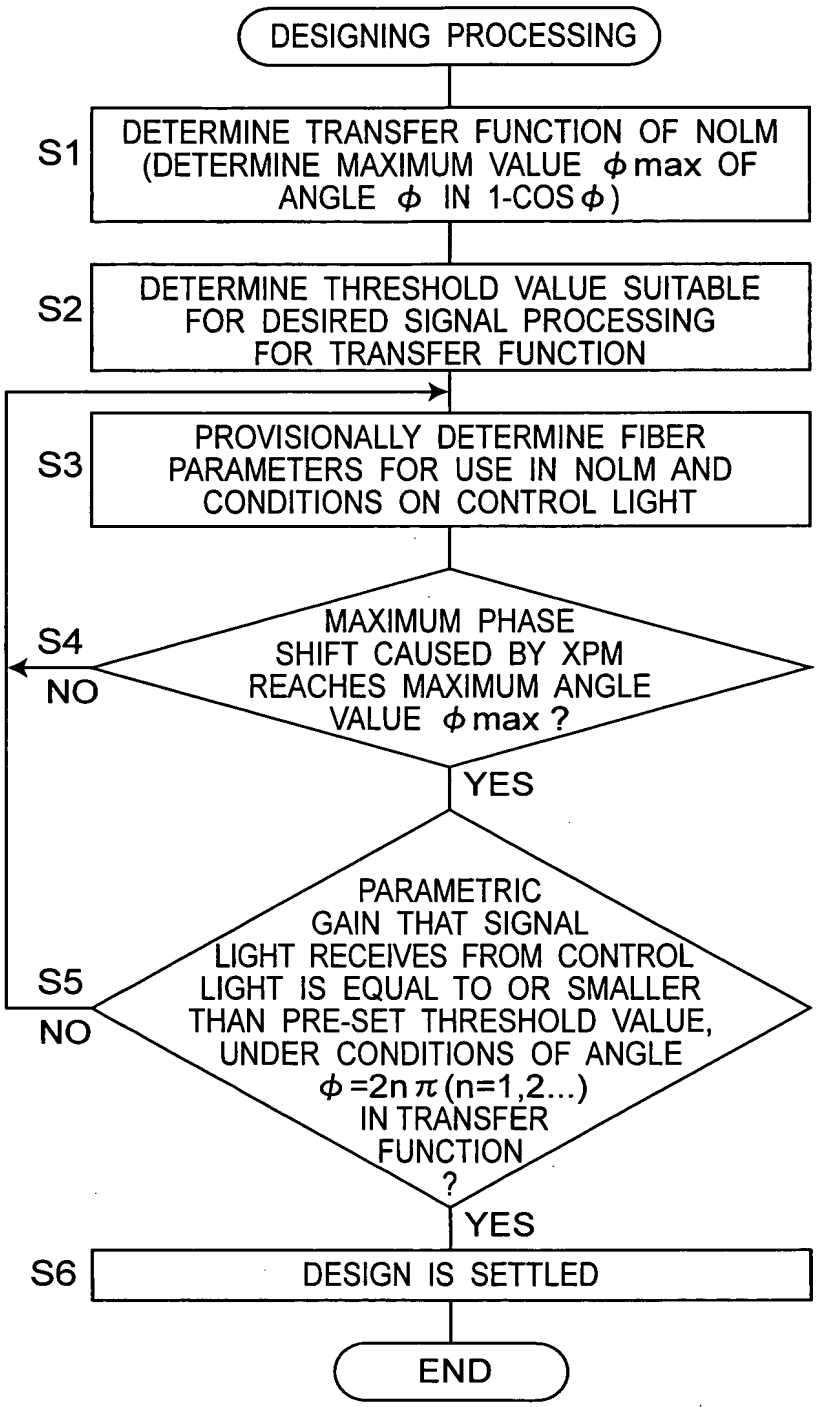

DISPERSION D(λ)
WAVELENGTH λ
CONTROL LIGHT
(PUMP LIGHT)
SIGNAL
LIGHT
λc
λs
λ0
ANOMALOUS
DISPERSION
0
NORMAL
DISPERSION
D(λc)

Fig.45


DESIGNING PROCESSING
S1
DETERMINE TRANSFER FUNCTION OF NOLM (DETERMINE MAXIMUM VALUE φmax OF ANGLE φ IN 1-COSφ)
S2
DETERMINE THRESHOLD VALUE SUITABLE FOR DESIRED SIGNAL PROCESSING FOR TRANSFER FUNCTION
S3
PROVISIONALLY DETERMINE FIBER PARAMETERS FOR USE IN NOLM AND CONDITIONS ON CONTROL LIGHT
S4
MAXIMUM PHASE SHIFT CAUSED BY XPM REACHES MAXIMUM ANGLE VALUE φmax ?
NO
YES
S5
PARAMETRIC GAIN THAT SIGNAL LIGHT RECEIVES FROM CONTROL LIGHT IS EQUAL TO OR SMALLER THAN PRE-SET THRESHOLD VALUE, UNDER CONDITIONS OF ANGLE φ=2nπ(n=1,2...) IN TRANSFER FUNCTION ?
NO
YES
S6
DESIGN IS SETTLED
END

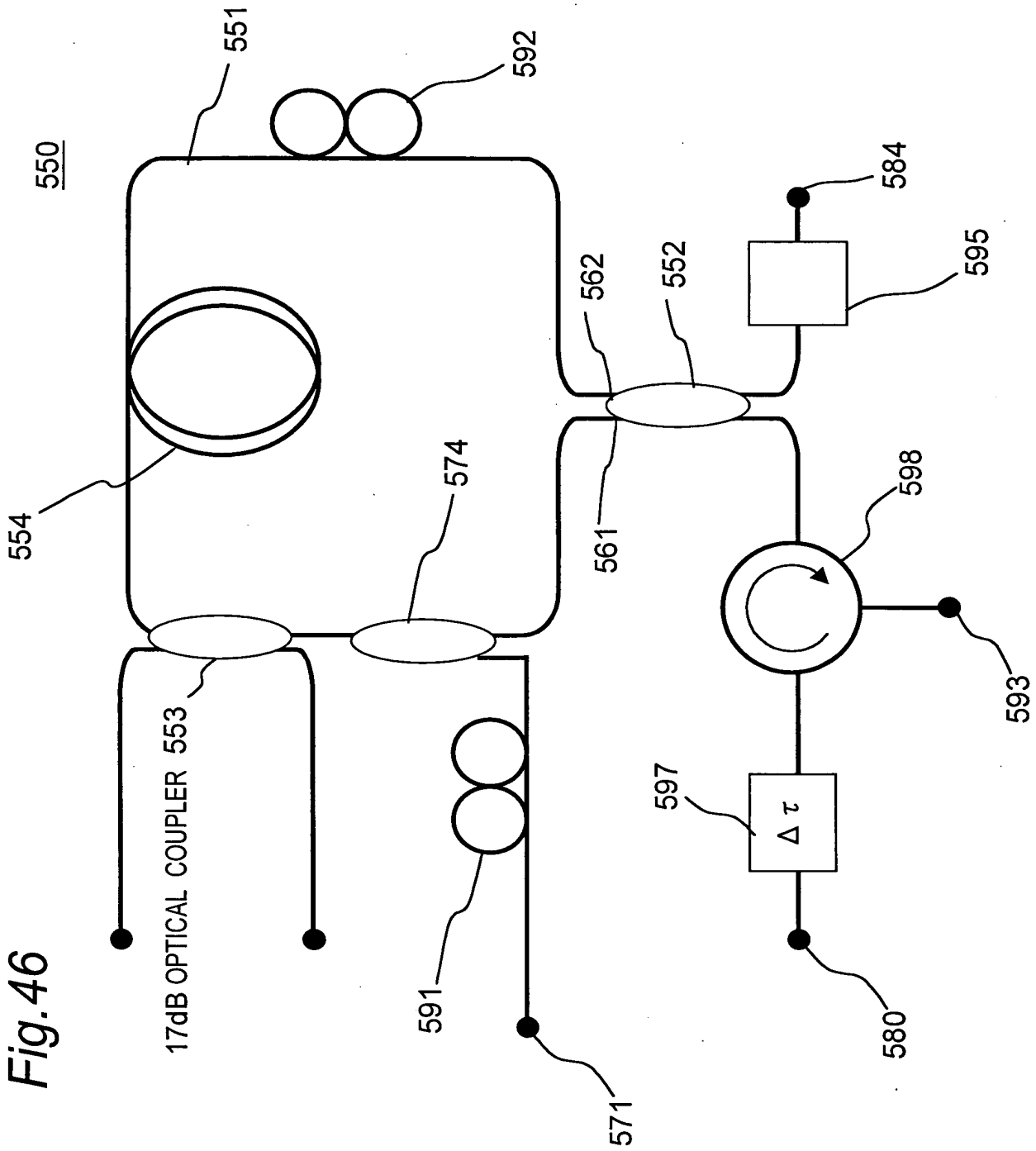
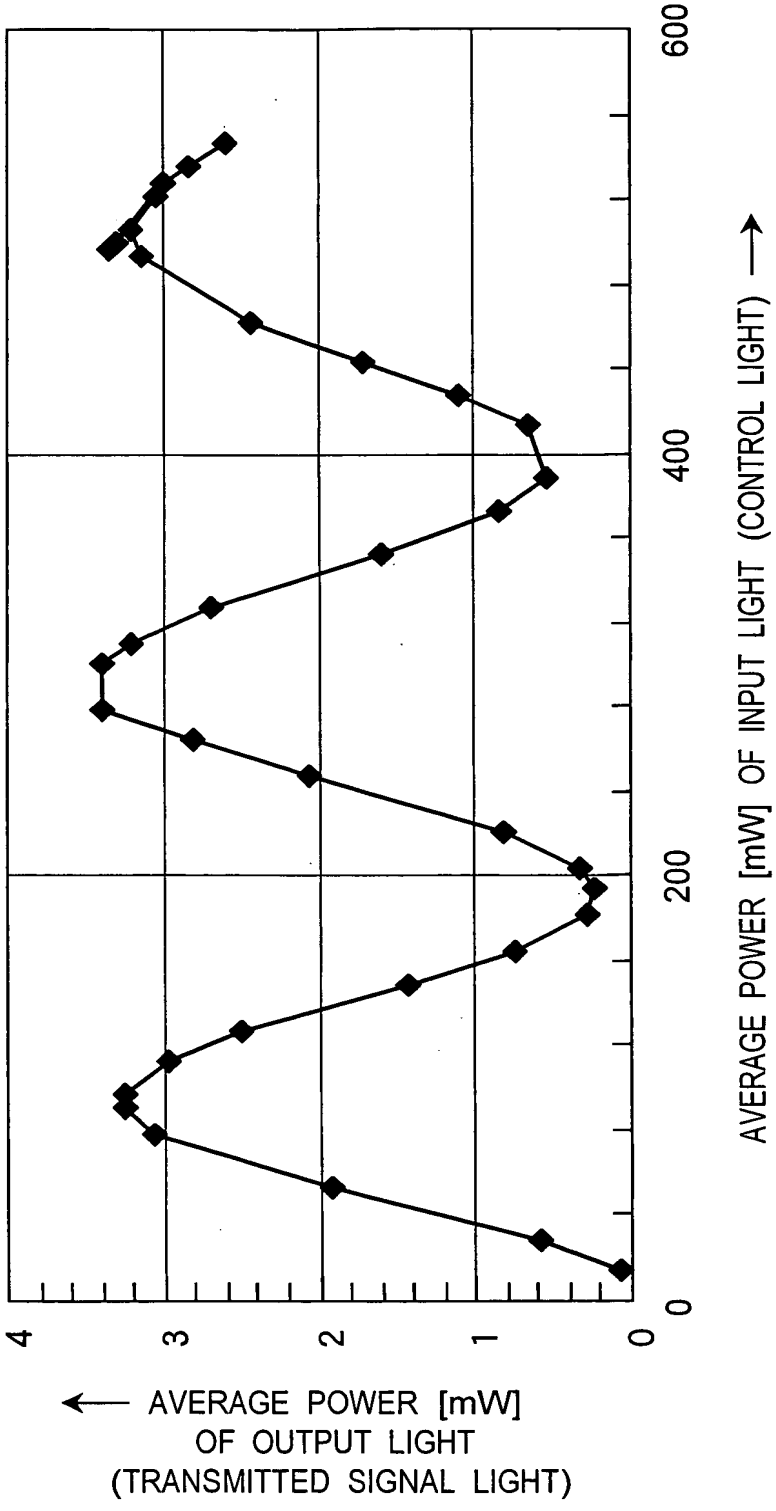

550
551
592
584
595
562
552
554
574
561
598
593
17dB OPTICAL COUPLER 553
591
597
Δ τ
580
571

Fig.46

Fig.47


0
200
400
600
AVERAGE POWER [mW] OF INPUT LIGHT (CONTROL LIGHT)
0
1
2
3
4
AVERAGE POWER [mW]
OF OUTPUT LIGHT
(TRANSMITTED SIGNAL LIGHT)

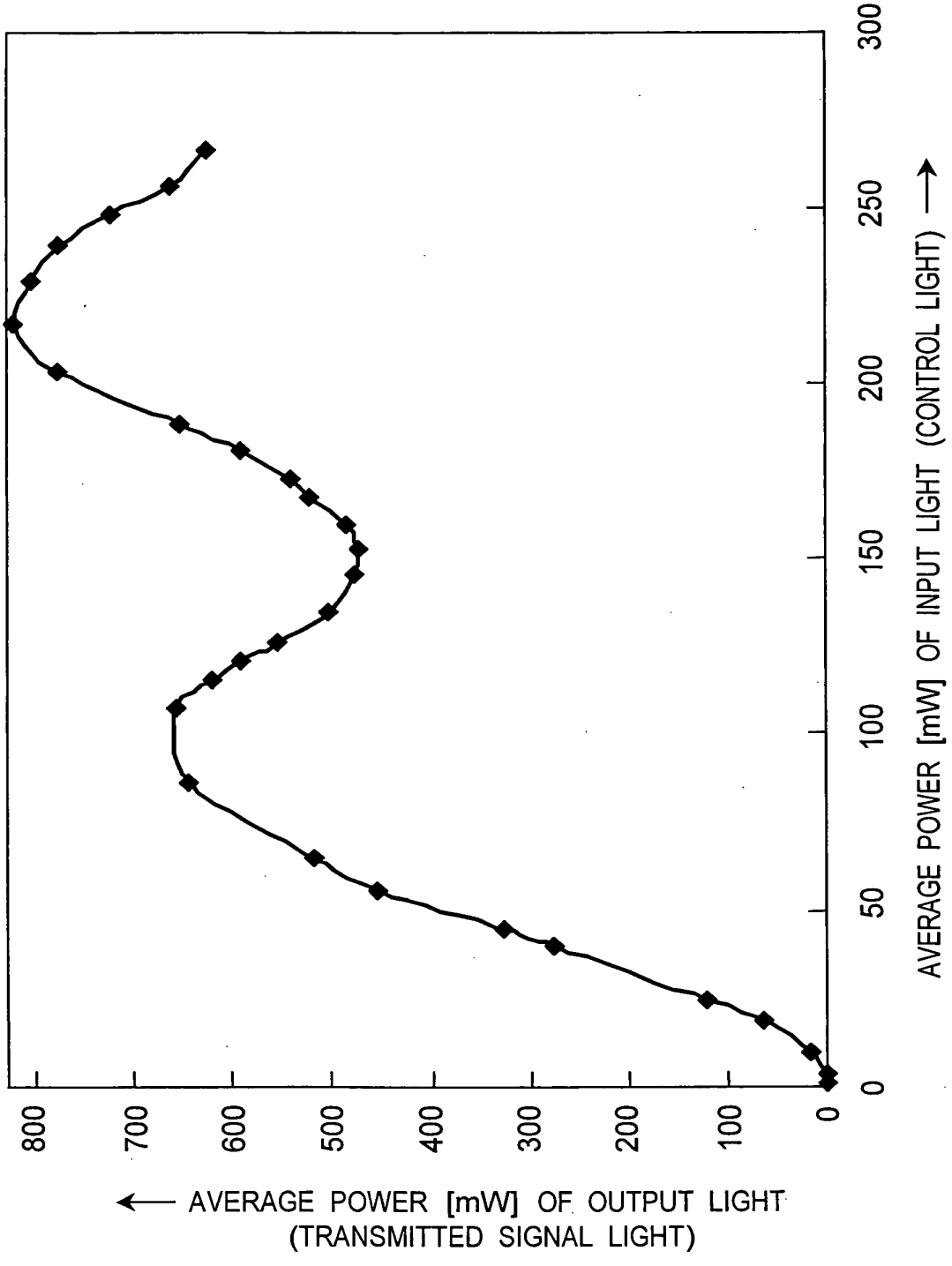

800
700
600
500
400
300
200
100
0
← AVERAGE POWER [mW] OF OUTPUT LIGHT
(TRANSMITTED SIGNAL LIGHT)
0
50
100
150
200
250
300
AVERAGE POWER [mW] OF INPUT LIGHT (CONTROL LIGHT) →

Fig.48

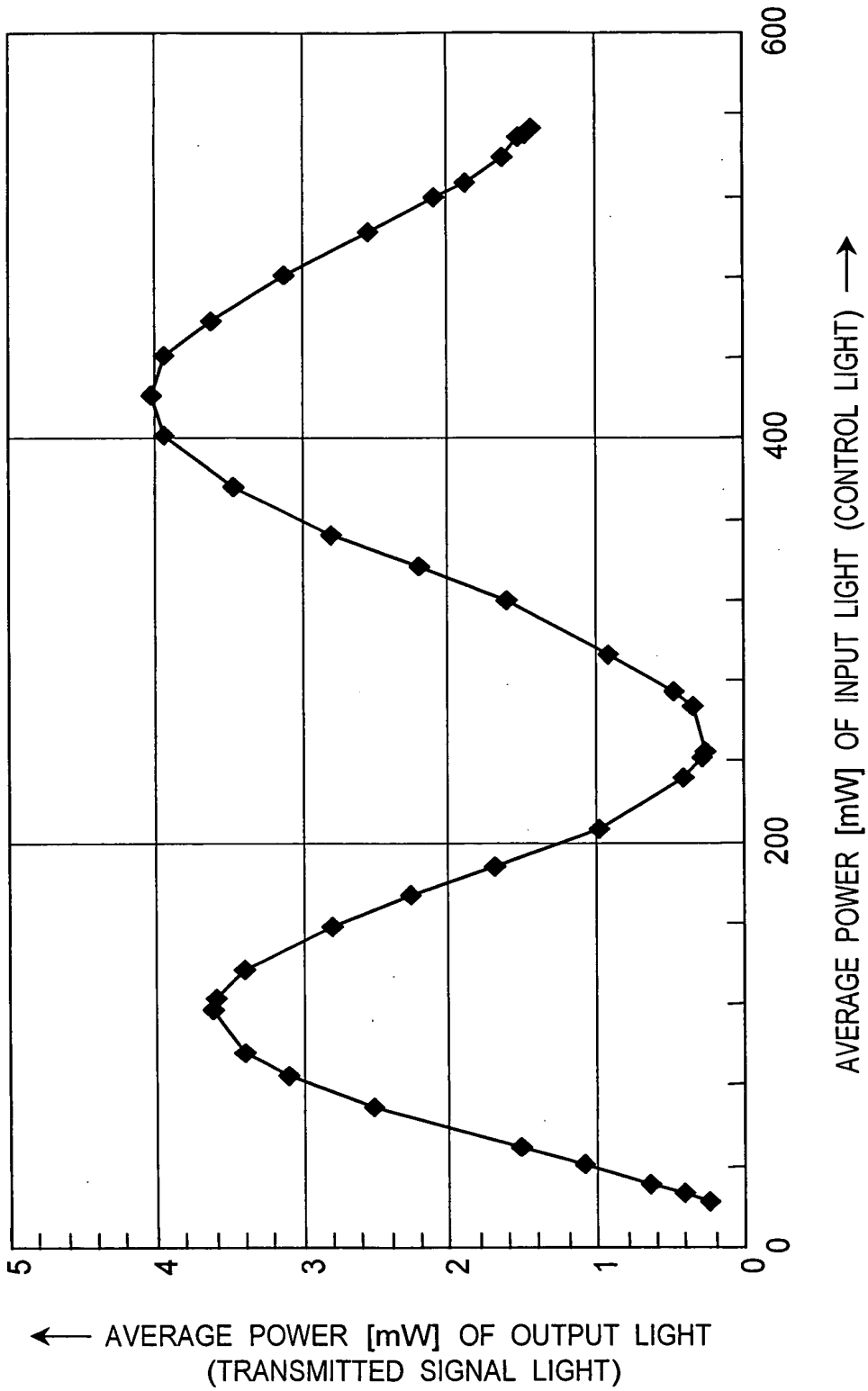

0
1
2
3
4
5
← AVERAGE POWER [mW] OF OUTPUT LIGHT
(TRANSMITTED SIGNAL LIGHT)
0
200
400
600
AVERAGE POWER [mW] OF INPUT LIGHT (CONTROL LIGHT) →

Fig.49

Fig.50

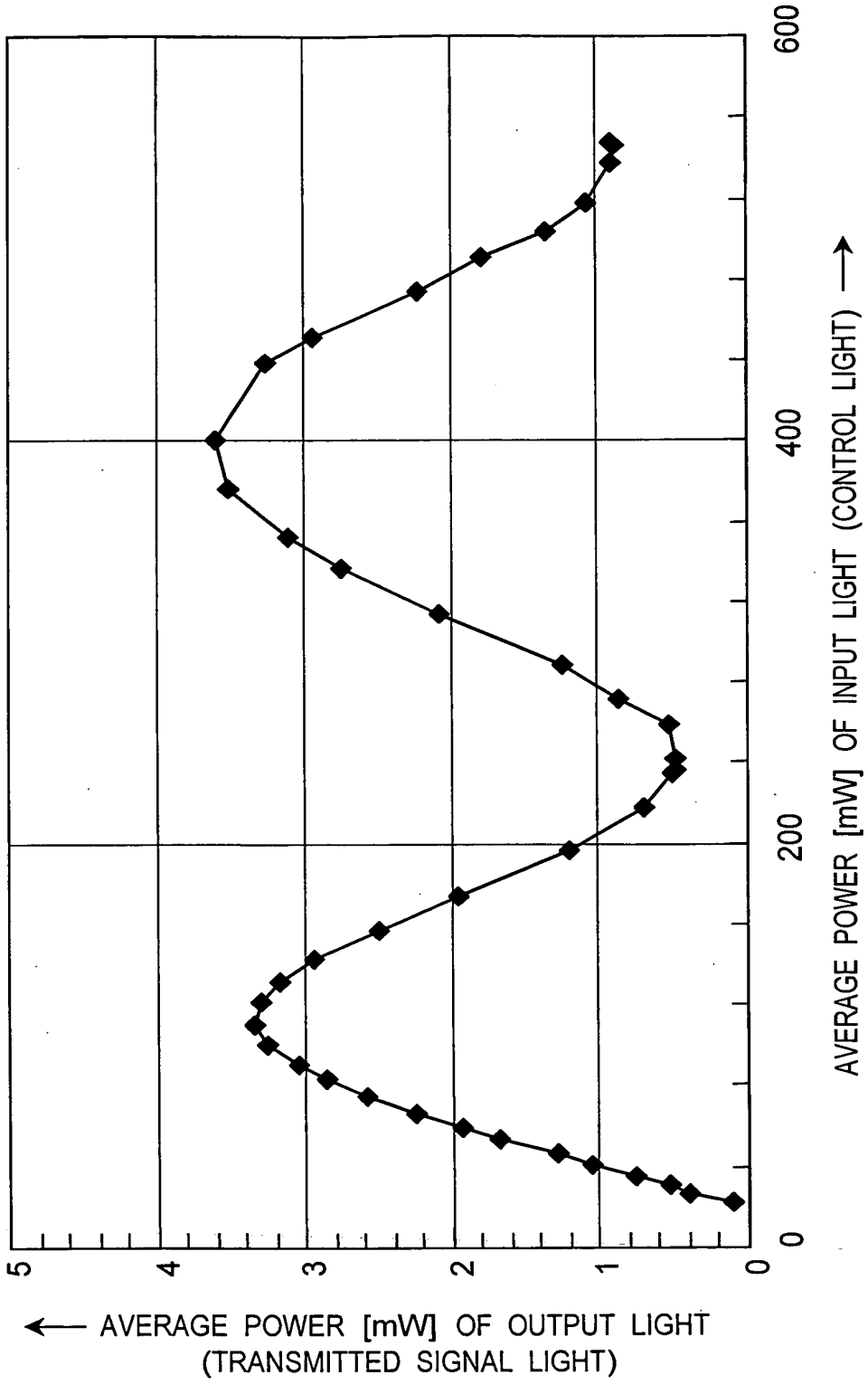

0
200
400
600
AVERAGE POWER [mW] OF INPUT LIGHT (CONTROL LIGHT)
0
1
2
3
4
5
AVERAGE POWER [mW] OF OUTPUT LIGHT
(TRANSMITTED SIGNAL LIGHT)

Fig.51

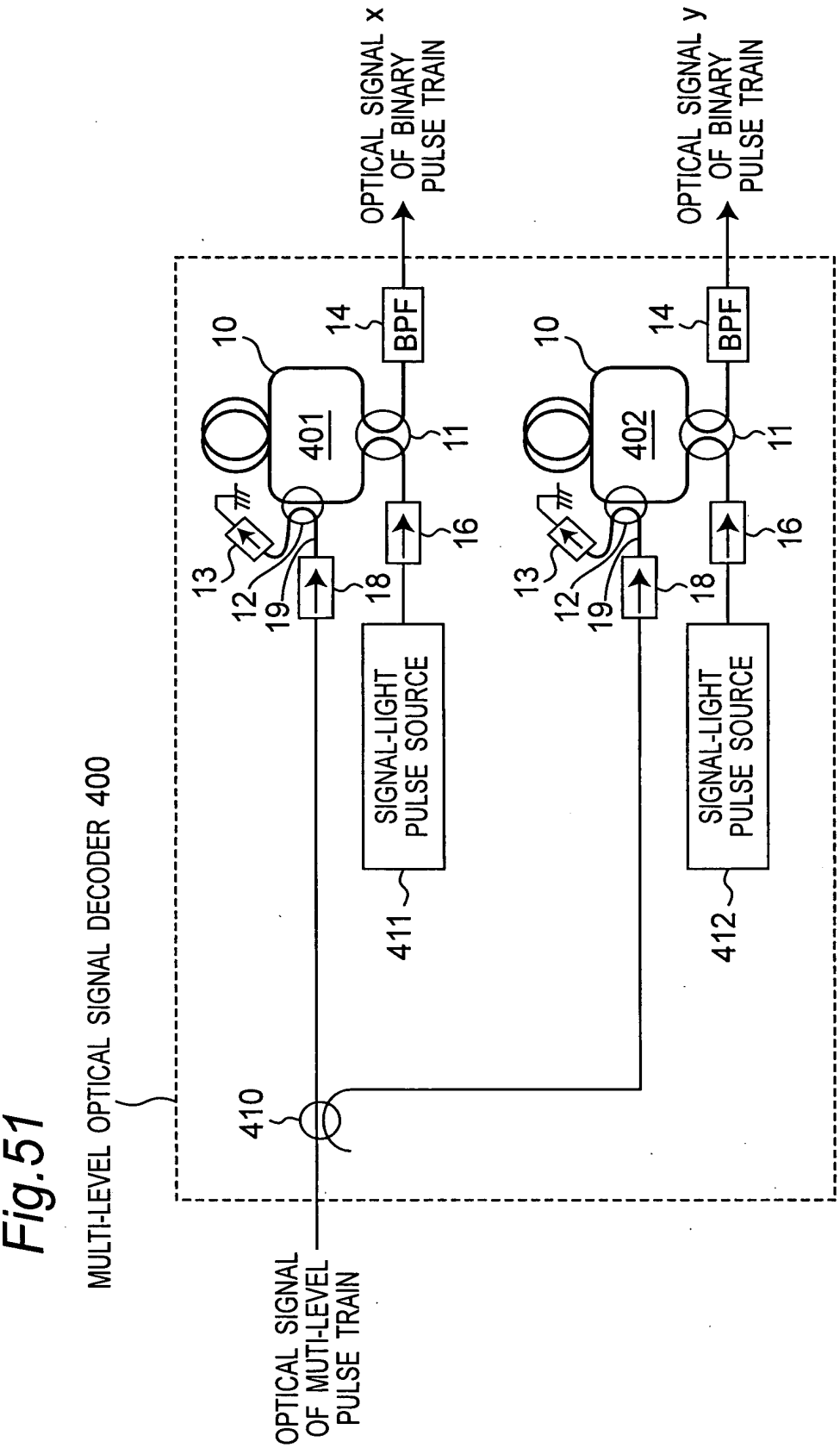

MULTI-LEVEL OPTICAL SIGNAL DECODER 400
OPTICAL SIGNAL OF MUTI-LEVEL PULSE TRAIN
410
401
402
10
11
12
13
14
16
18
19
BPF
SIGNAL-LIGHT PULSE SOURCE
411
412
OPTICAL SIGNAL x OF BINARY PULSE TRAIN
OPTICAL SIGNAL y OF BINARY PULSE TRAIN

Fig.52

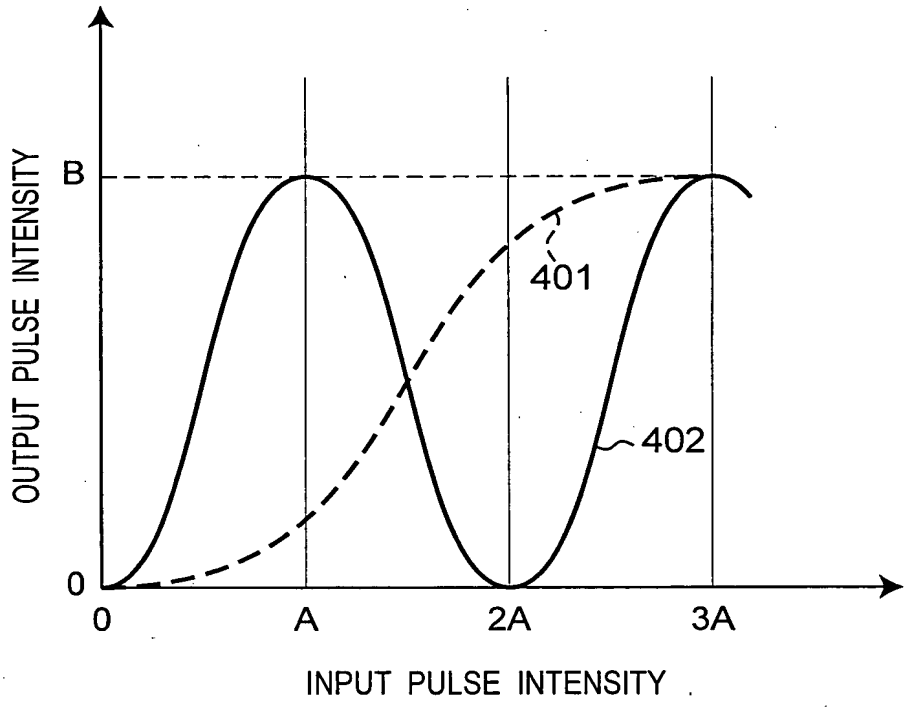

OUTPUT PULSE INTENSITY
B
0
0
A
2A
3A
INPUT PULSE INTENSITY
401
402

Fig.53

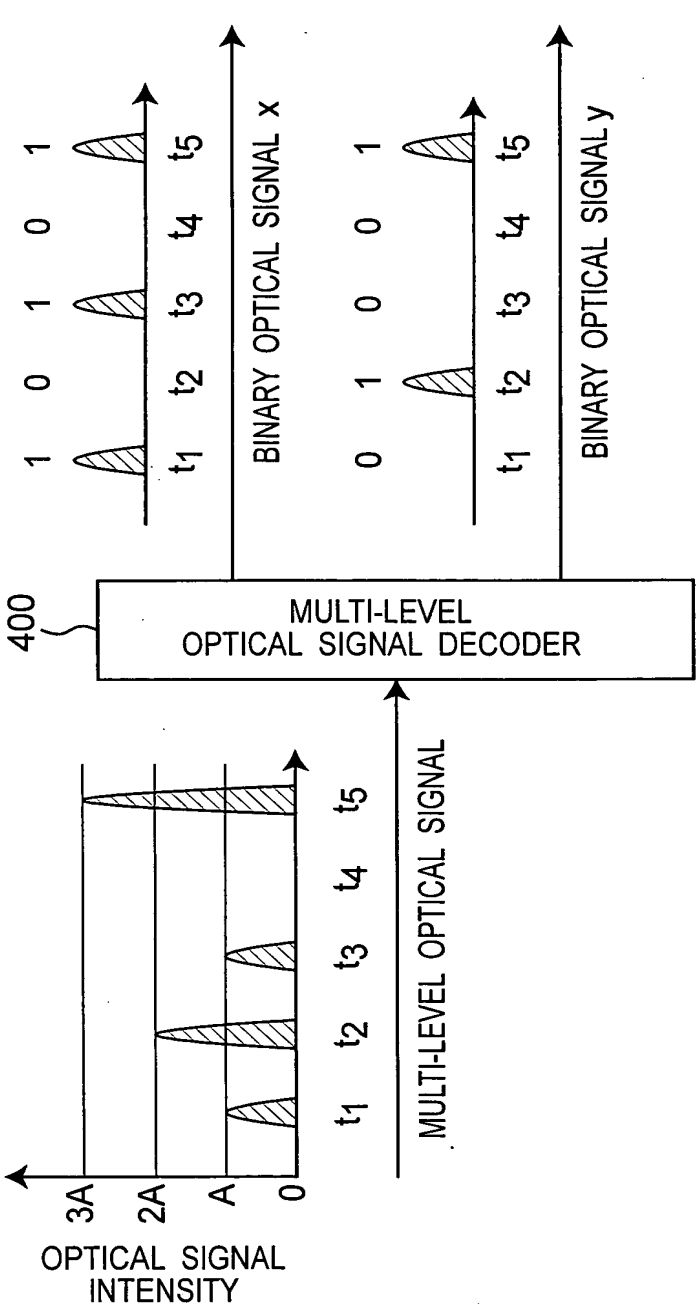

OPTICAL SIGNAL INTENSITY
3A
2A
A
0
t1 t2 t3 t4 t5
MULTI-LEVEL OPTICAL SIGNAL
400
MULTI-LEVEL OPTICAL SIGNAL DECODER
BINARY OPTICAL SIGNAL x
1 0 1 0 1
t1 t2 t3 t4 t5
BINARY OPTICAL SIGNAL y
0 1 0 0 1
t1 t2 t3 t4 t5

Fig.54

x	y	OPTICAL SIGNAL INTENSITY
0	0	0
1	0	A
0	1	2A
1	1	3A

Fig.55

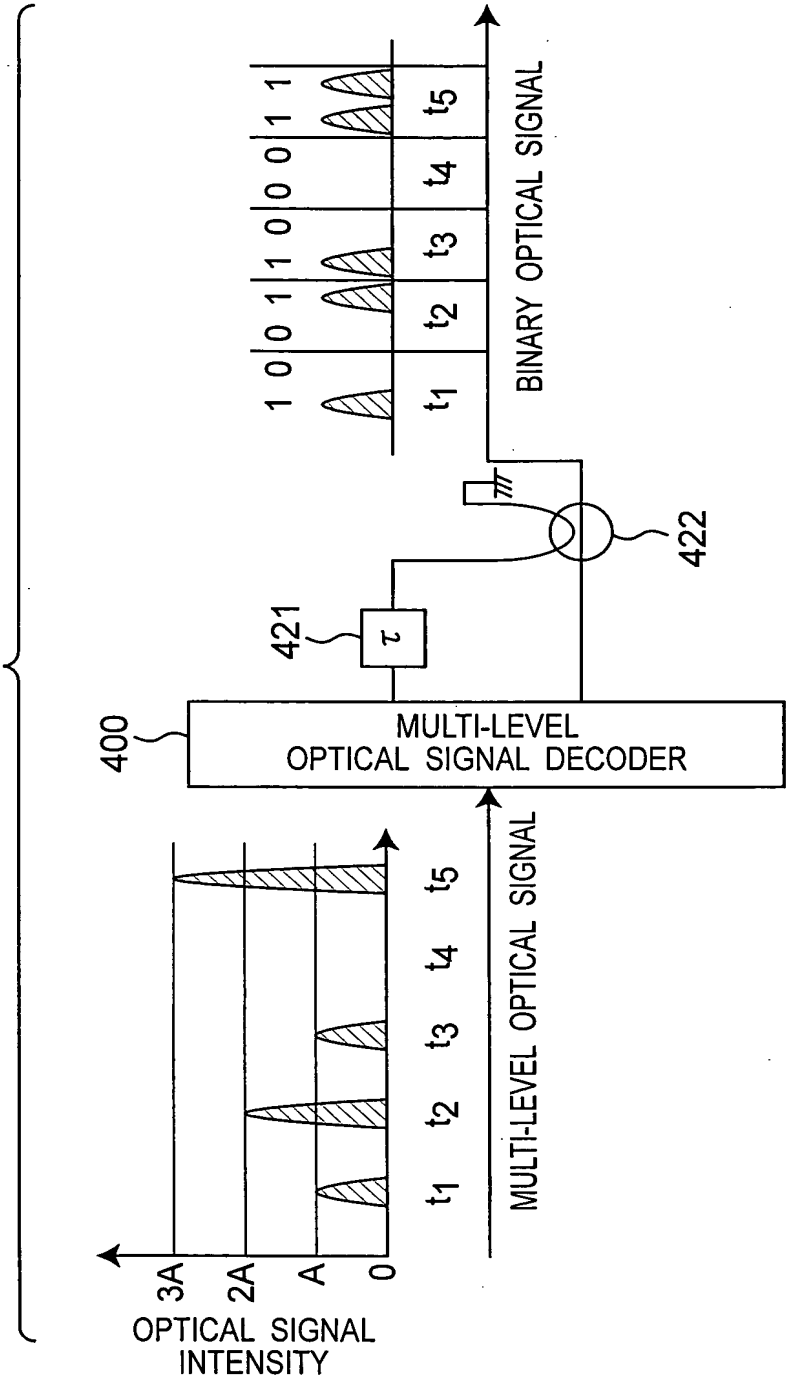

OPTICAL SIGNAL INTENSITY
3A
2A
A
0
t1
t2
t3
t4
t5
MULTI-LEVEL OPTICAL SIGNAL
400
MULTI-LEVEL OPTICAL SIGNAL DECODER
421
τ
422
BINARY OPTICAL SIGNAL
1 0 0 1 1 0 0 0 1 1
t1
t2
t3
t4
t5

Fig.56

CODE	OPTICAL SIGNAL INTENSITY
00	0
10	A
01	2A
11	3A

Fig.57

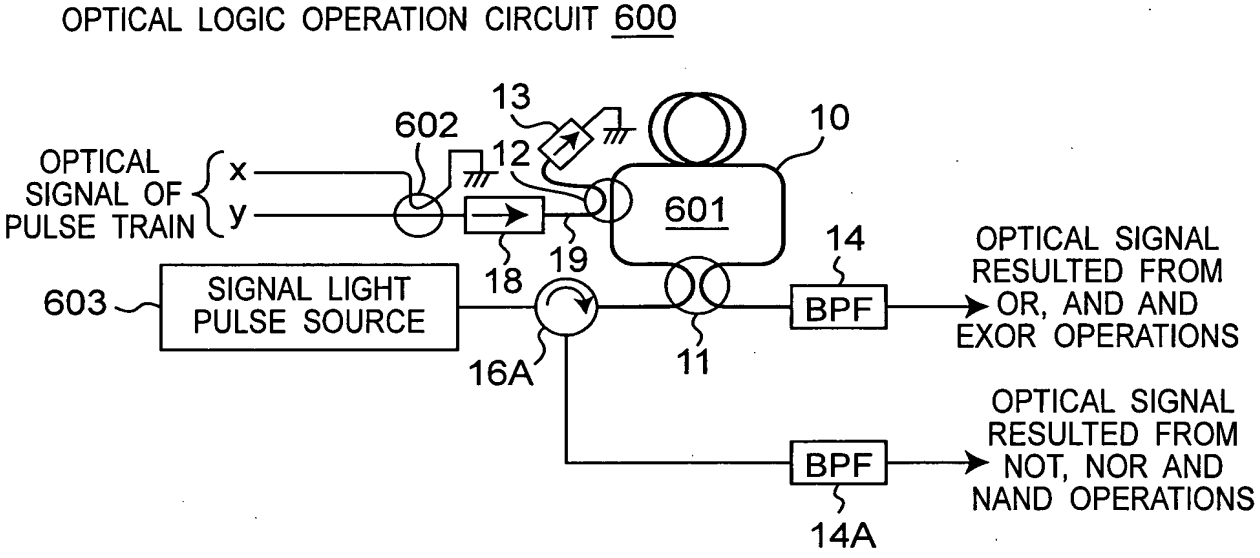

OPTICAL LOGIC OPERATION CIRCUIT 600
13
602
10
12
OPTICAL SIGNAL OF PULSE TRAIN
x
y
601
14
19
18
603
SIGNAL LIGHT PULSE SOURCE
BPF
OPTICAL SIGNAL RESULTED FROM OR, AND AND EXOR OPERATIONS
16A
11
OPTICAL SIGNAL RESULTED FROM NOT, NOR AND NAND OPERATIONS
BPF
14A

Fig.58

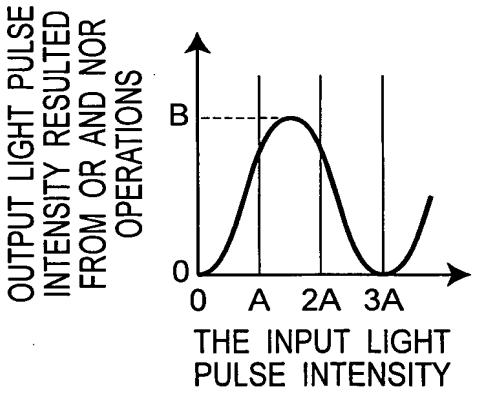

OUTPUT LIGHT PULSE INTENSITY RESULTED FROM OR AND NOR OPERATIONS
B
0
0
A
2A
3A
THE INPUT LIGHT PULSE INTENSITY

Fig.59

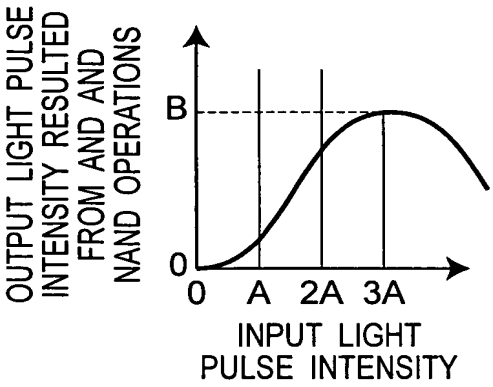


Fig.60

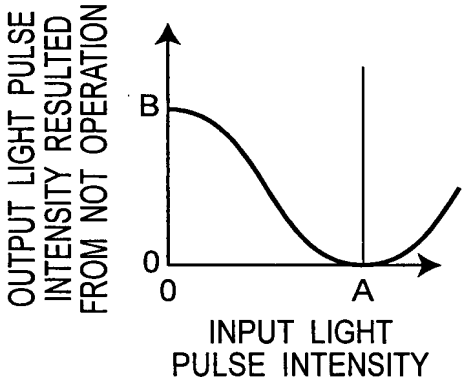


Fig.61

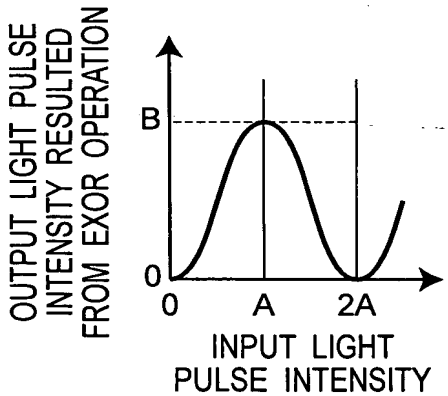


Fig. 62

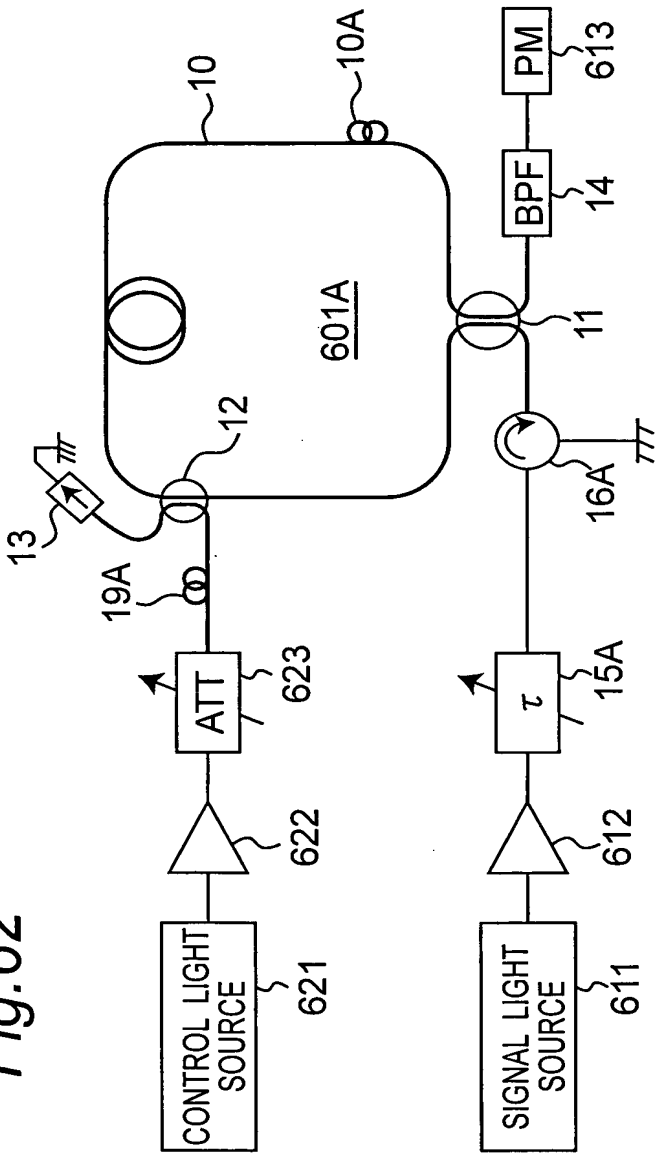
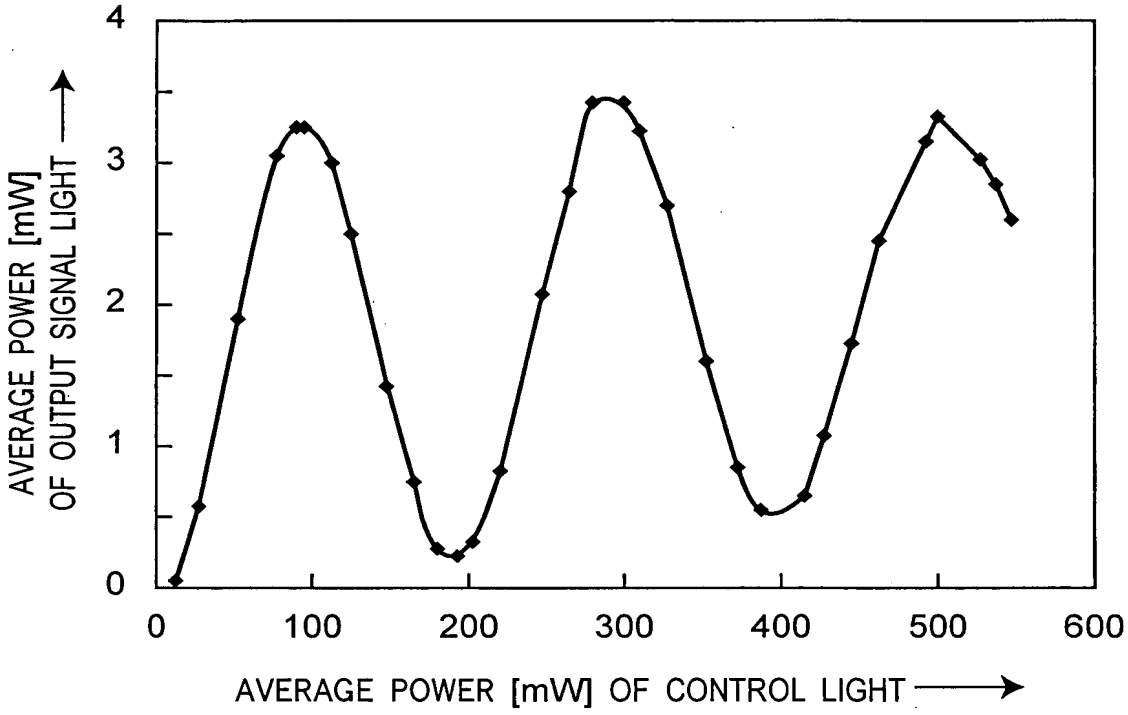

CONTROL LIGHT SOURCE
621
622
ATT
623
19A
13
12
10
10A
601A
11
BPF
14
PM
613
SIGNAL LIGHT SOURCE
611
612
τ
15A
16A

Fig.63


AVERAGE POWER [mW] OF OUTPUT SIGNAL LIGHT
0
1
2
3
4
0
100
200
300
400
500
600
AVERAGE POWER [mW] OF CONTROL LIGHT

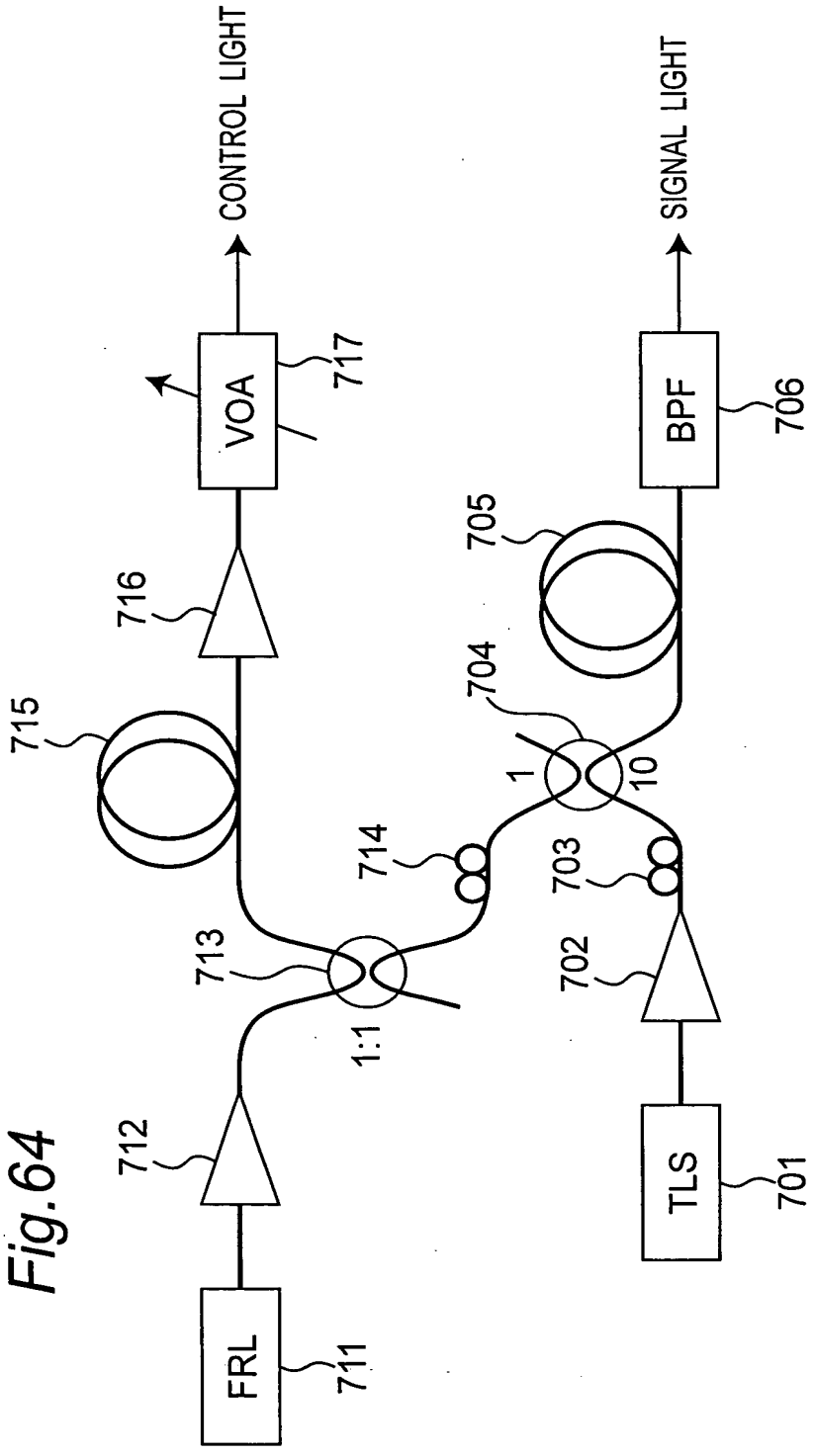

CONTROL LIGHT
SIGNAL LIGHT
VOA
BPF
TLS
FRL
1:1
1
10
711
712
713
714
715
716
717
701
702
703
704
705
706

Fig.64

Fig.65

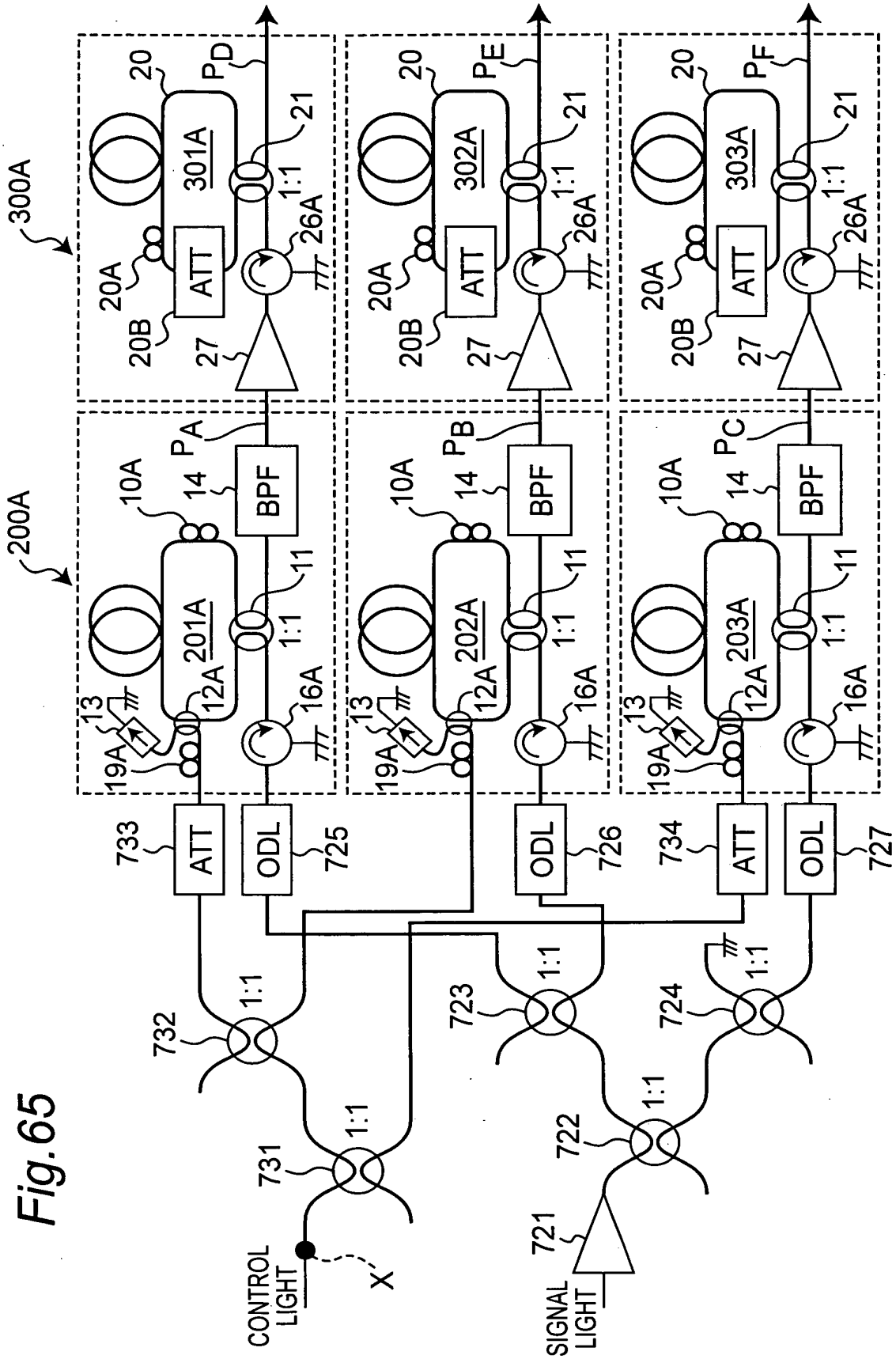

300A
200A
301A
302A
303A
201A
202A
203A
ATT
BPF
ODL
1:1
CONTROL LIGHT
SIGNAL LIGHT
X

Fig.66

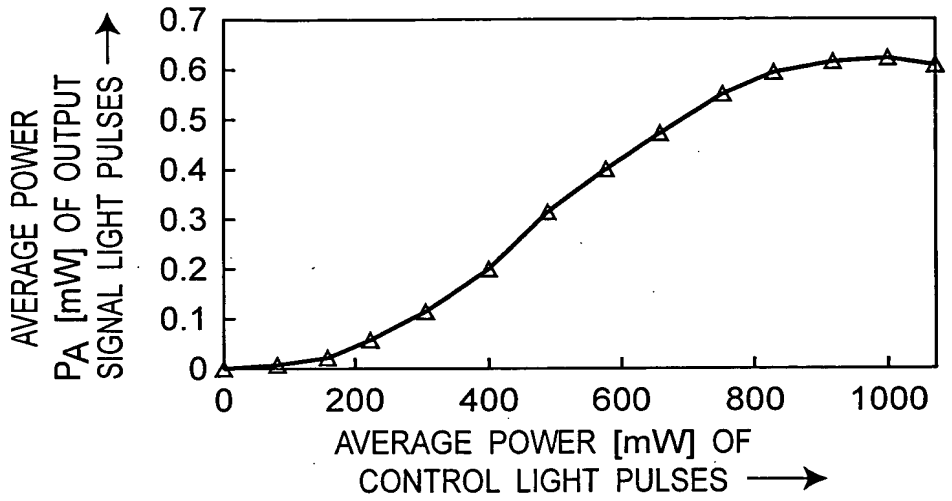


Fig.67

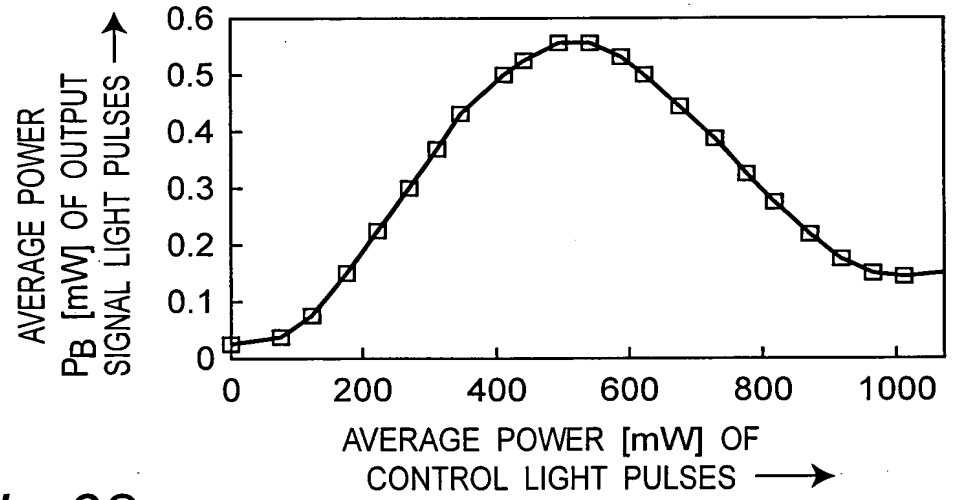


Fig.68

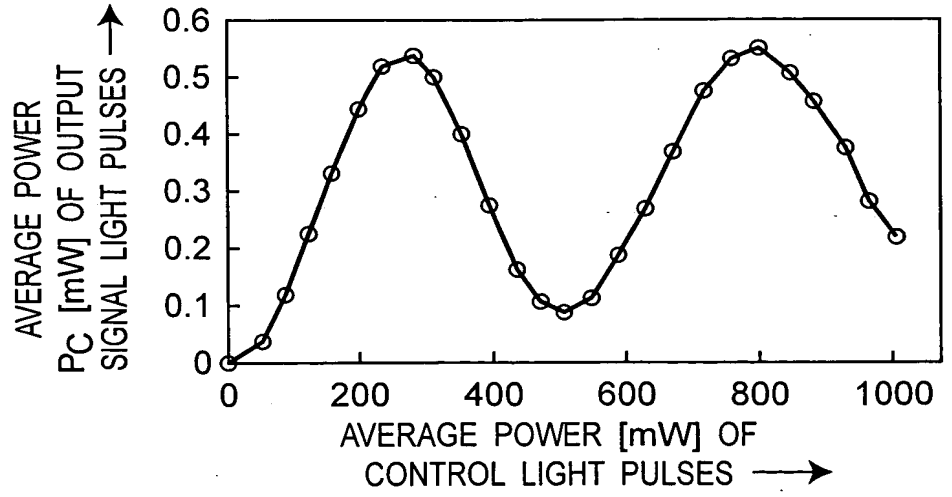


Fig.69

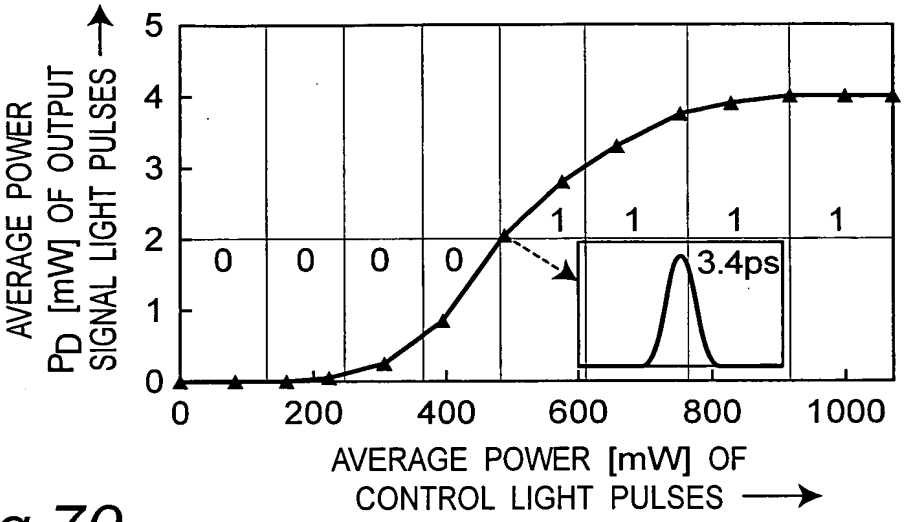


Fig.70

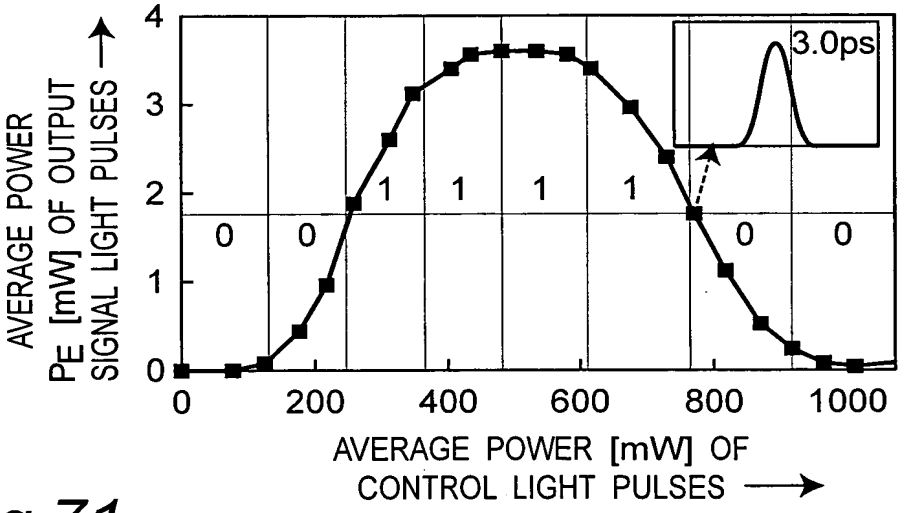
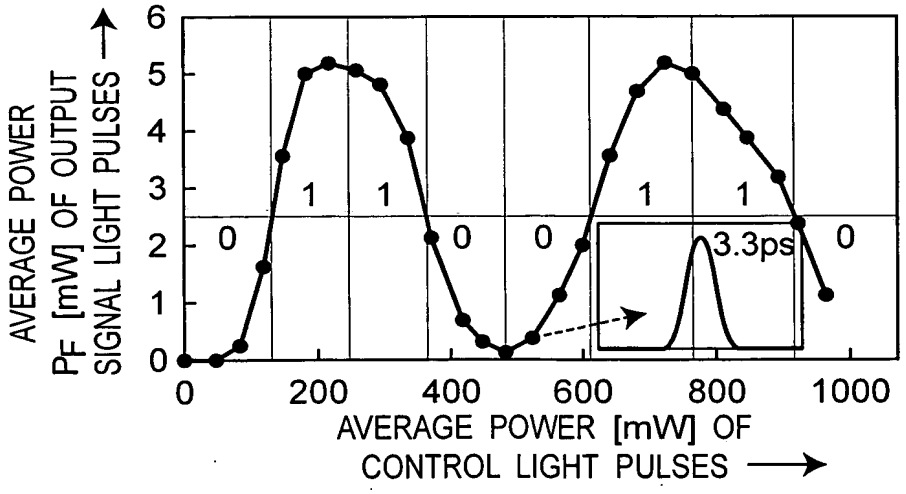
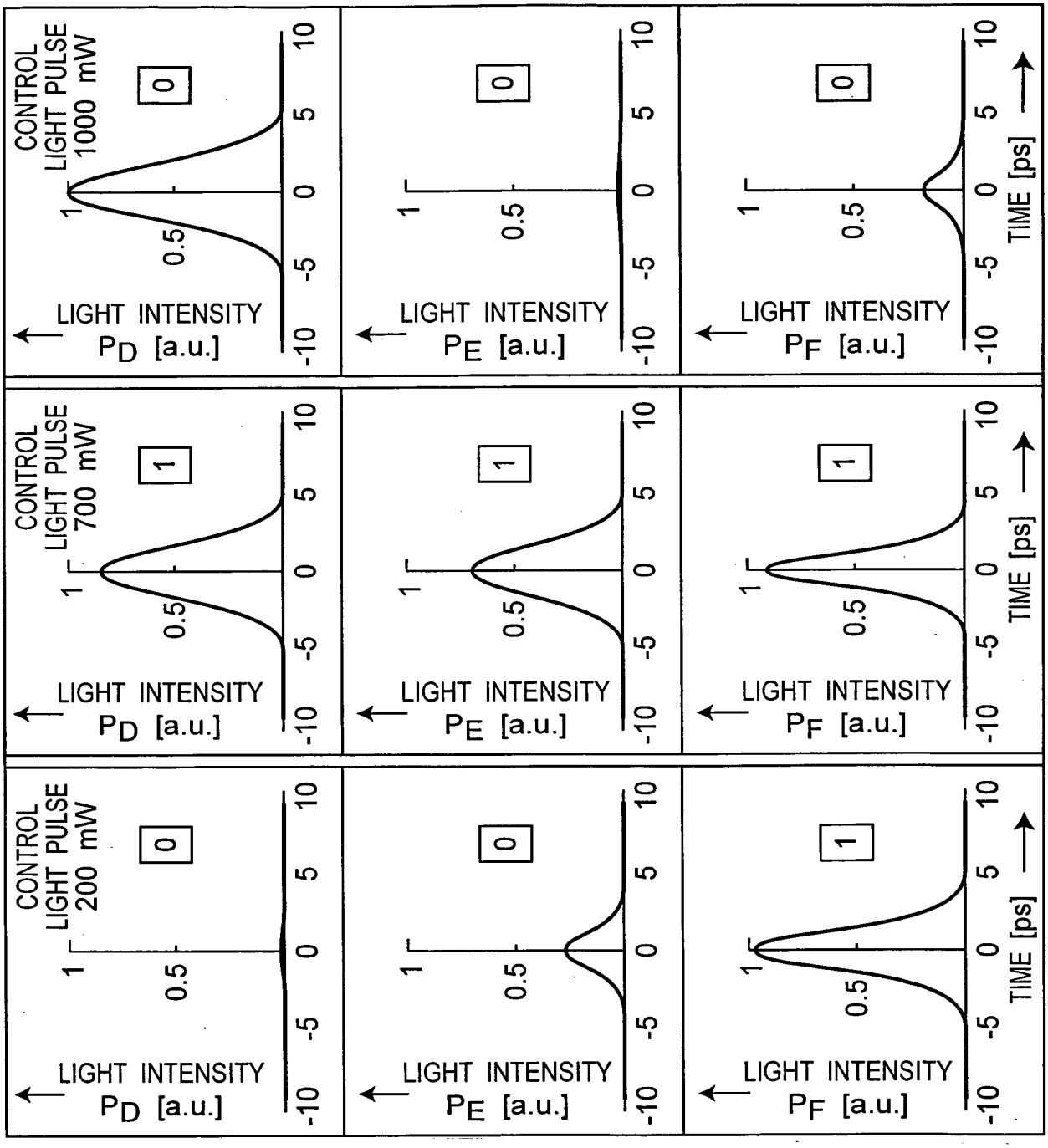


Fig.71

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CONTROL LIGHT PULSE 700 mW
CONTROL LIGHT PULSE 200 mW
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LIGHT INTENSITY
P_D [a.u.]
P_E [a.u.]
P_F [a.u.]
TIME [ps]
1
0.5
10
5
0
-5
-10

Fig. 72